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NEW EXPERIMENTS
ON
ELECTRICITY,

WHEREIN

THE CAUSES OF THUNDER AND LIGHTNING

AS WELL AS THE CONSTANT STATE OF

Positive or negative Electricity in the Air or
Clouds, are explained;

WITH

Experiments on Clouds of POWDERS and VAPOURS
ARTIFICIALLY DIFFUSED IN THE AIR.

ALSO

A DESCRIPTION OF
A DOUBLER of ELECTRICITY,

AND OF THE MOST

SENSIBLE ELECTROMETER YET CONSTRUCTED.

WITH OTHER

New Experiments and Discoveries in the Science,

ILLUSTRATED BY EXPLANATORY PLATES.

By the Rev. A. BENNET, F.R.S.
Curate of WIRKSWORTH, *Derbyshire*.

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124

TO THE
REVEREND
Dr. RICHARD KAYE, F.R.S. & F.S.A.
DEAN OF LINCOLN,
AND
TRUSTEE
OF THE
BRITISH MUSEUM,
THIS
WORK
IS DEDICATED,
BY
HIS OBLIGED
HUMBLE SERVANT
ABRAHAM BENNET.





THE AUTHOR takes this opportunity of expressing his most sincere thanks to his subscribers, and especially to the following ladies and gentlemen who have liberally encouraged his work, and recommended it to their numerous and respectable friends.

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CONTENTS.



C O N T E N T S.

Introduction, containing a short theory of electricity.

S E C T I O N I.

Description of a gold leaf electrometer.

Slips of tinfoil increase the sensibility of the electrometer. Exp. 1.

Slips of tinfoil take off the influence of the cap. Exp. 2.

S E C T I O N II.

Powdered chalk blown upon the electrometer. Exp. 1 to 7.

Some of its varieties explained. — Exp. 7.

Experiment to shew the effect of influential atmospheres. Exp. 8.

Chalk projected from a brush. - - - - - Exp. 9.

The brush electrified contrary to the cloud of powder. Exp. 10.

Electrometer charged positively by the influence of a negative cloud of powder. - - - - - Exp. 11.

Chalk and dust projected several ways. - - - - - Exp. 12 & 13.

All powders negative except flour, oatmeal, and minium. Exp. 14.

The electricity of powders not owing to friction. Exp. 15 to 17.

Chalk more strongly electrified than flour. - - - - - Exp. 18.

Flame collects electricity in circumstances where it would not otherwise become sensible. - - - - - Exp. 20 to 24.

Positive and negative electricity produced by evaporation in several new methods. - - - - - Exp. 26 to 30.

Atmospheric electricity collected by a Lantern. - - - - - Exp. 31 to 32.

By water spouted upwards. - - - - - Exp. 33.

Heat without effluviu does not dissipate electricity. Exp. 34.

Charge of the gold leaf electrometer too small to be dissipated by the sharpest points or edges. - - - - - Exp. 36 to 38.

S E C T I O N III.

New experiments with M. Lichtenburg's large electrophorus.

Powder'd chalk projected upon the figures in various ways, - - - - - Exp. 1 to 21.

<i>Minium and sulphur mixed are separately attracted by positive and negative figures.</i>	- - -	Exp. 22.
<i>Ramifications and shades explained.</i>	- - -	Exp. 23 to 27.
<i>The figures indelibly fixed on sealing wax.</i>	-	Exp. 28.
<i>The figures taken off on paper, leather, callico, or linen.</i>		Exp. 29.
<i>The figures fixed on porcelain.</i>	- - - -	Exp. 30.
<i>The figures preserved by framing the electrophorus.</i>	-	Exp. 31.
<i>More ways of varying the figures.</i>	- - .	Exp. 32 to 35.
<i>A convenient box for projecting powders without loss.</i>		Exp. 36.
<i>An electrical pen.</i>	- - - - -	Exp. 37.
<i>To make circles and other figures more conveniently.</i>	-	Exp. 38.
<i>Imitation of Fairy rings</i>	- - - -	Exp. 40.

SECTION IV.

Electricity excited by evaporation.

<i>Both states of electricity in one experiment.</i>	-	Exp. 1.
<i>Several metals heated and plunged in water.</i>	- -	Exp. 1 to 10.
<i>Green vegetables burnt.</i>	- - - -	Exp. 11.
<i>Dry wood, hay and cinders.</i>	- - -	Exp. 12 to 15.
<i>Salts, acids, oil and water.</i>	- - -	Exp. 16 to 22.
<i>Various substances dropped upon a hot iron.</i>		Exp. 23 to 46.
<i>Upon Bell metal.</i>	- - - . -	Exp. 47 to 48.
<i>A more convenient iron, with which more substances were tried.</i>	- - - -	Exp. 49 to 63.
<i>The ascending vapours examined.</i>	- -	Exp. 64 to 70.

SECTION V.

Description of a doubler of electricity.

SECTION VI.

Improvements of the doubler.

<i>A convenient method of depriving the doubler of its charge.</i>		
<i>The plates of the revolving doubler absorb more electricity when touched in a parallel position.</i>	- -	Exp. 1 & 2.
<i>Uninsulated approximating plates of different substances absorb electricity.</i>	- - -	Exp. 3 to 6.
		<i>The</i>

CONTENTS.

vii.

The condenser in its original state produces a strong spontaneous charge of electricity. - - - Exp. 7.

SECTION VII.

Experiments on adhesive electricity.

By the double contact of hardened steel and soft iron. Exp. 1 & 2.

Lead ore and lead. - - - Table 1.

Lead and iron wire. - - - Table 2.

Lead ore and iron wire. - - - Table 3.

Tinfoil and iron wire. - - - Table 4.

Zinc and iron wire. - - - Table 5.

By single contact of lead ore and zinc alternately. - Table 6.

Zinc applied to A and B separately. - - Table 7.

Lead ore applied to A and B separately. - - Table 8.

Suggestions for improving the accuracy of the revolving doubler.

Adhesive electricity explains the excitation of rubbed electrics.

SECTION VIII.

A short theory of atmospheric electricity.

Description of a convenient apparatus for observing the state of atmospheric electricity in all sorts of weather.

Convulsive motion of the gold leaf electrometer, occasioned by a thunder cloud. - - - Obs. 1.

Positive and negative state of showers. - - Obs. 2 to 5.

A thunder cloud which caused 10 changes of electricity in the space of an hour and a half. - - Obs. 6.

Clouds and rain. - - - Obs. 7 to 12.

Serene sky. - - - Obs. 13.

Clouds and rain. - - - Obs. 14 to 16.

Mist. - - - Obs. 17.

Thunder cloud. - - - Obs. 18.

Rain and mist. - - - Obs. 19 to 21.

Snow, mist and rain. - - - Obs. 22 to 25.

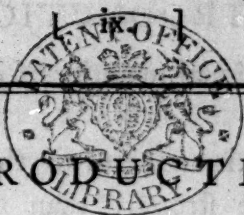
Sleet and rain. - - - Obs. 26 & 27.

A 4

Snow

<i>Snow.</i>	- - - - -	Obs. 28.
<i>Mist, snow and sleet.</i>	- - - - -	Obs. 29 to 31.
<i>Wind and hail.</i>	- - - - -	Obs. 32 & 33.
<i>Thunder cloud.</i>	- - - - -	Obs. 34.
<i>Serene weather.</i>	- - - - -	Obs. 35 to 38.
<i>Heavy shower wholly positive.</i>	- - - - -	Obs. 39.
<i>Experiment in dry air.</i>	- - - - -	Obs. 40.
<i>Thunder cloud.</i>	- - - - -	Obs. 41.
<i>Aurora Borealis.</i>	- - - - -	Obs. 42 & 43.
<i>Ten changes of electricity during a shower.</i>	- - - - -	Obs. 44.
<i>A severe shock from a kite string.</i>	- - - - -	Obs. 45.
<i>Aurora Borealis.</i>	- - - - -	Obs. 46.
<i>Several clouds positive and negative without rain.</i>	- - - - -	Obs. 48 & 49.
<i>Snow.</i>	- - - - -	Obs. 50.

INTRODUCTION.



INTRODUCTION.

BY the desire of some of my friends I am induced to prefix a concise theory of Electricity, that the reader may more easily comprehend the intention and use of the following experiments.

1st. Electricity is an extremely subtle fluid, which pervades metals with astonishing facility. It also pervades water, moist vegetables, animals, and many other substances more imperfectly. These substances are termed perfect and imperfect conductors. But amber, glass, silk, oil, dry air, and some other bodies are impervious to the electrical fluid; and because when rubbed they shewed signs of electricity adhering to them, it was once supposed, that they were the only bodies which contained electricity, and were therefore termed electrics.

That some bodies are conductors and others electrics or non-conductors does not appear to depend on their specific gravity; for gold is the best conductor, and of the greatest specific gravity; and air, which is so much less dense, does not conduct; but charcoal is a good conductor, and lighter than glass, which is an electric. It is not improbable but that this property may depend on the chemical affinity of their component parts with the electrical fluid. If electrics are supposed to have in their composition a large quantity of fixed electricity as limestone contains fixed air, they may be impervious

ous to any additional quantity of it, because already saturated.

2dly. Electricity adheres to the surface of electrics much more strongly than to the surface of conductors, and hence when two such substances are rubbed together, part of the natural quantity of fluid belonging to the conductor adheres to the electric. Without this property of electricity its existence might never have been discovered, but first on rubbing amber and then other electrics some of its effects were observed, and after gradual improvements the present electrical machines were constructed, and various other discoveries made.

3dly. Electricity is a very elastic fluid, so that it may be condensed or accumulated upon any substance, whose connection with the earth is cut off by the interposition of an electric. This is termed insulation. Electricity, thus accumulated, repels the natural electricity of the surrounding air, disposing it to recede, which is then termed an electrical atmosphere, whose density according to the demonstration of the Earl of Stanhope, in his learned principles of electricity is proved to be in the inverse ratio of the square of the distance.

An accumulation of electricity which disposes that of the surrounding air to be repelled is termed a positive electrical atmosphere. But if the same insulated body be deprived of its natural quantity of this fluid, it disposes the surrounding air to absorb more electricity, and this also produces an atmosphere which is termed negative.

If

If light conducting substances as bits of gold leaf be brought within an electrical atmosphere, they become attracted towards the electrified body : for the density of the electrical atmosphere increases towards the centre, and the power of its attraction being proportionate to its density, whatever light conducting substances are immersed in the extreme parts will move towards the centre till they touch the electrified body and receive a part of its electricity.

When the gold leaf has touched the electrified body, which thus attracted it, and has received from it a part of its electricity it becomes repelled ; because the superinduced electricity will attract a quantity of air to form round itself another atmosphere, whose electricity it tends to repel like the body which was first electrified, and therefore either the light substance will move off till it comes into air whose electricity is not repelled by the influence of the first electrified body, or a double quantity of air must be attracted into the same space, or lastly the intensity of the electrical atmosphere between the two bodies must diminish, which always happens when the two electrified bodies are immovable. The same effects will take place whether the atmosphere be positive or negative, for every substance has as strong a tendency to absorb its natural quantity of electricity, as it has to emit or dissipate a superfluous quantity. This explanation of electrical repulsion easily applies to the divergency of cork or pith balls or the still lighter shreds of gold leaf used in the several kinds of sensible electrometers.

The

The electrical attraction and repulsion of light substances may be illustrated by cork balls or other light bodies swimming on water, which adhering round them is raised above or depressed below the common level, and causes the corks to be attracted towards or repelled from each other. When two cork balls are equally moistened and the adhering water is raised above the level surface, or when both the corks are dry and the surrounding water is depressed below the level surface, the corks are attracted, which may not seem to agree with the case of electrification, for two equally electrified bodies repel each other, but if two light bodies were electrified in a perfectly exhausted glass, where the air could not interfere, it is probable that they would not repel but attract each other, from the tendency in fluids to unite and form one globular mass, as two globules of clean quicksilver unite when brought into contact.

Two light substances electrified in the open air repel each other, because their electricity strongly attracts the air, which coming between pushes them asunder, and in like manner the two corks swimming on water will be repelled, if one of them be made to raise its surrounding atmosphere of water above the common surface, and the other to depress it; for in this case the level surface may be considered as a third substance flowing in and attracted by each cork to complete its atmosphere, which pushes the corks asunder. This experiment may be conveniently tried, by pressing two bits of thin writing paper upon a round hole about half an inch in diameter

meter, so as to make the paper concave ; then let the edges be pared, and they will form two small paper cups, which are to be placed upon the surface of a basin of water ; let a little fine sand be put into these cups that the edges of the paper may be depressed below the level surface of the water, and then the two loaded cups will approach, and at last come into contact with each other, then let the edge of a moistened piece of paper be placed in the direction of a tangent line between the cups, and they will suddenly recede to the distance of several inches.

Every method of condensing or rarifying the electrical fluid may be explained by the principle of adhesive attraction : but I shall here only mention the practical method of rubbing a stick of sealing wax or rather a glass tube about five inches long covered with sealing wax upon woollen cloth, for the purpose of trying the quality of electricity communicated to an electrometer. It is well known that the sealing wax thus rubbed is excited negatively, that is the natural electricity of the sealing wax is left upon the woollen, and its atmosphere being brought so near as to touch the atmosphere of the electrometer the gold leaf will either diverge wider or collapse ; if it diverges more, its electricity is negative like that of the sealing wax ; but if it collapses, it is positive.

4thly. Electricity may be accumulated in a much greater degree upon one side of a thin electric as a plate of glass or a bottle, if the opposite side be connected with the earth by means of a conductor, for

as

as electricity is condensed on one side of the glass the natural electricity is rarified on the other, and the restoration of the equilibrium between the two sides, causes the effect termed an electrical shock, and that the fluid may be more speedily diffused over or discharged from the surface of the glass it is coated with tinfoil except near the edges. Fluid electrics may also be charged, but because the charge might otherwise soon break through, the two coatings must be farther distant from each other, except when the quantity of electricity is small. There is one remarkable difference between the charge of a solid and a fluid electric, which is, that the charge principally adheres to the surface of the solid electric and not to its coating: but when a plate of air is charged it adheres to the coating: on this consideration was founded the contrivance of the doubler of electricity hereafter described.

That some quality of accumulated electricity should act through electrics which are impervious to the fluid itself, and cause their natural electricity to expand so as to produce an electrical atmosphere; or repel the natural electricity on the opposite side of an electric in the case of charging the leyden bottle, are facts which have long been admired, and though most of the extraordinary effects of electricity depend on this property, yet I think it has never been very satisfactorily explained. If the elasticity of fluids in general was clearly understood, I doubt not but this difficulty would be surmounted, and if the opinions of Des Cartes on this subject were verified by experiments

periments they might gain credit, notwithstanding the general fallacy of his principles. “ Rara corpora illa sunt, inter quorum partes multa intervalla existunt, corporibus aliis repleta. Ut cum videmus spongiam aqua vel alio liquore turgentem. Etsi cum aer aut aqua sit rarefacta, non videamus ullos ipsorum poros qui ampliores reddantur, nec ullum novum corpus, quod ad illos replendos accedat; non est tamen rationi tam consentaneum, aliquid non intelligibile effingere, ad eorum rarefactionem verbotenus explicandam, quam ex hoc quod rarefiant, concludere, in ipsis esse poros, five intervalla quæ ampliora redduntur, & novum aliquod corpus accedere, quod ipsa implet; etsi hoc novum corpus nullo sensu percipiamus. Nulla enim ratio nos cogit ad credendum, corpora omnia quæ existunt debere sensus nostros afficere.”

Des Cartes Prin. Philos.

Par. 2. Sect. 6.

What is here said of the rarefaction of air and water may be applied to the rarefaction of electricity, that is there appears no way of accounting for it but by the supposition of another fluid strongly adhering to and mixed with it, and which is sufficiently subtle to pass thro' glass. On this hypothesis it is easy to conceive such mixed fluid accumulated in a bottle by the action of an electrical machine, and as the charge goes on and the fluid is condensed by being forced into a less space than it would

would otherwise occupy, the fluid which can pass thro' glass is forced out and would rarify all the surrounding electricity, by uniting with it, like heat diffused amongst colder bodies, but being every where insulated, it is confined, except on the outside of the bottle, where because the surface is connected with the earth its electricity can pass off. Light is so constantly emitted or excited by electrical sparks and so readily passes thro' glass that it might reasonably be suspected to be combined with the electrical fluid and be the cause of its elasticity, but some experiments do not seem to favour this supposition particularly sect. 2d. Exp. 34.

By these few principles the chief effects of electricity as far as they are yet known may be in some measure explained; but it is impossible to acquire an adequate knowledge of it without an attentive performance of experiments: for altho' I believe electricity is entirely subject to the same laws with every other substance, yet because it hath some qualities in a very high degree as subtilty, elasticity and adhesive attraction, and others scarcely at all as gravitation and solidity, it is very difficult without experiments to become impressed with a just notion concerning them.

Since the performance of experiments is so necessary to those who wish to acquire a more accurate knowledge of electricity, I beg leave here to suggest that the gold leaf electrometer, may without partiality to my own contrivance, be recommended, as the first instrument to be used, and the contents of the

INTRODUCTION.

xvii.

the following sections may serve for introductory lessons as well as any other. And if the more laborious and troublesome part of the science shou'd not be approved, there is sufficient scope for instructive varieties in the use of the electrometer and doubler without more cumbersome machinery, so that the author hopes, that ladies as well as gentlemen, who have honoured him with their patronage, will here find some amusement.

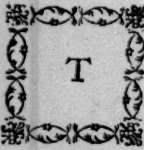
B

SECTION

New Experiments, &c.

SECTION I.

Description of a gold leaf electrometer.

 HIS instrument principally consists of two narrow slips of gold leaf suspended in the middle of a hollow cylindrical glass.

The foot A plate 1, may be made of metal or wood, and about three inches high, that there may be convenient room to handle the instrument without touching the glass. The cylindrical glass B in which the gold leaf is suspended may be about five inches high, and two inches in diameter. The cap C is made of metal, and flat on the top, that the various substances whose electricity is to be examined may be conveniently placed upon it. The diameter of the cap is about an inch more than that of the glass, and its rim D is about an inch broad and hangs parallel to the glass to keep it clean and dry. Within this is another circular rim about half as broad as the other, made to go over or within the glass, and is therefore lined or covered with leather, or other soft substance, to make it fit close, and thus the

the cap may be easily taken off to repair any accident happening to the gold leaf. Within this rim and in the centre of the cap a tube is fixed, wherein the peg E is placed. To the peg, which is made round at one end and flat at the other, two slips of gold leaf F are fastened with paste, gum water or varnish.

If gold leaf is used it may be shorter than silver leaf. The gold is much more sensible, but the silver is easier to cut and less liable to be accidentally torn. I have mostly used gold about two inches long, tapering to a fine point and fastened to the peg at the broad end. The breadth of the upper end of the gold is about one fifth of an inch, which keeps the slips more exactly parallel, and the electrical repulsion is more sensible when the points are narrow, as I have observed when an accidental very narrow slip hung by the side of two parallel ones, the narrow slip always moving first.

Without the glass the gold leaf would be so agitated by the least motion of the air that it would be entirely useless, and if electricity should be communicated to the sides, the gold would be attracted and torn, therefore two pieces of polished tinfoil G H are fastened with varnish on opposite sides of the internal surface where the gold leaf may be expected to strike, and are connected with the foot of the electrometer. The breadth of the tinfoil at the foot is one fourth of the circumference of the glass, and it terminates in a point towards the cap, about as high as the peg to which the gold leaf is fastened. It is

broad at the bottom, because there the points of the gold leaf are most liable to strike the glass, and being made narrow upwards does not prevent the repulsion from being easily observed.

These slips of tinfoil, not only carry off superfluous electricity, but serve other important purposes, as will appear from these two experiments.

EXPERIMENT I.

Upon a supposition that the gold leaf was attracted by the tinfoil, I suspended it in the open air, without a glass, and when electrified I brought two wires near it, and the gold leaves open'd wider, till they touched and collapsed, then upon bringing the wires still nearer they again diverged, which proved that the two pieces of tinfoil were useful to increase the sensibility of the instrument.

EXPERIMENT II.

I fastened the gold leaf to the inside of an iron mortar hanging by a silk string with the mouth downwards, and though I communicated to it as much electricity as it would receive, the gold leaf did not diverge till a wire was introduced; which first caused the points to open, and then the higher part of the gold, as the wire came nearer to the place where the gold was fastened. This experiment shews that the tinfoil takes off the influence of the cap which would otherwise diminish the repulsion of the gold leaf.

The upper end of the glass is covered and lined with sealing wax, at least as low as the outermost rim;

to

to render its insulation more perfect, for sealing-wax does not collect moisture from the air so soon as glass. In performing this operation, the glass shou'd be gradually heated over a candle till it will cause the wax to flow uniformly over the surface, for if it be covered whilst the glass is cooler than the wax it will not insulate so perfectly. The foot may be about three inches and an half in diameter at the bottom, that the instrument may stand sufficiently firm.

An electrometer of this kind has been carried from Birmingham to London; another from Wirksworth to York, and a third from Wirksworth to Etruria in a portmanteau on horseback, yet without injury; it is therefore easy to make electrometers less in every dimension, especially in diameter, whereby their sensibility is increased, and inclose them in a proper case to carry in the pocket, to observe the atmospheric electricity whilst on a journey, or on the top of a mountain. For some purposes it may be also necessary to make them larger. In many experiments I have used one about five inches in diameter, which shew'd the changes in the atmospheric electricity more distinctly than a smaller electrometer whose gold leaf would sooner strike the sides.

The broad cap of this large electrometer was also very convenient for placing upon it red hot crucibles or vessels of water in experiments on evaporation.

SECTION II.

Experiments on clouds of powders and vapours artificially diffused in the air, and other experiments illustrating the principles of electricity, and shewing the great sensibility of the gold leaf electrometer.

EXPERIMENT I.

POWDER'D chalk was put into a pair of bellows and blown upon the cap of the electrometer, placed at the distance of about six inches, which electrified it positively. See plate 3 fig. 7.

EXPERIMENT II.

Powder'd chalk was blown from the bellows towards the electrometer placed at the distance of three feet, which caused the gold leaf to diverge negatively.

EXPERIMENT III.

The cap of the electrometer was moistened, and the powder'd chalk blown upon it at the distance of six inches, which electrified it negatively, contrary to the dry cap at the same distance.

EXPERIMENT IV.

Two electrometers were placed with their caps about an inch asunder, the one moist and the other dry, and a stream of powder from the bellows at the distance of six inches was made to pass between the caps, which electrified the one positively, and the other negatively.

EXP!

EXPERIMENT V.

If a bunch of wire, feathers, or silk, were placed in the bellows, the electrometer was negatived at the same distance which produced a positive state without them; also blowing gently with the bellows without the iron pipe, (by which means the powder was more widely diffused in the air) had the same effect.

EXPERIMENT VI.

A red hot stone was placed upon an insulating stand connected with the electrometer, and when powder'd chalk was blown upon it from the bellows within the distance of six inches, it became strongly and permanently negative.

EXPERIMENT VII.

If the person who blows the powder'd chalk into the air from the bellows be insulated by standing upon a stool with glass feet, and after blowing touch the cap of the electrometer, the gold leaf will diverge positively.

When the bellows produced positive electricity on the dry cap, or negative on the moist one, the cap was permanently electrified: but the negative state of the powder, blown at the distance of three feet, was not communicated; the gold leaf collapsing as the powder passed away.

Since the moist cap or hot stone produce a negative state of electricity within six inches, the one by detaining the powder, and the other attracting its

electricity by means of hot effluvia, it appears that the whole stream is properly negative: but the powder continues to deposit electricity as it passes out of the bellows, and tho' it has lost some in its way, yet it will electrify the cap positively whilst thus in the act of changing its state.

To exemplify this let two metal balls be insulated, and let one of them receive a spark, then bring it near the second ball, and it will cause the natural electricity of this second ball to pass off and electrify any substance touching it positively, and this second ball is left properly negative: but let the first ball approach nearer, and notwithstanding its negative state, the second ball will still communicate positive electricity. By this example it is evident that the powder may communicate positive electricity whilst under the influence of some cause which renders it negative; this cause I suppose to be the contact of air, which has a greater or less affinity with the electrical fluid than the powder, and therefore when it is suddenly projected into the air, each particle is disposed by this contact of air to absorb or emit electricity as it leaves the earth, and in passing along, the chalk deposits electricity upon the dry cap, whilst the same powder is acquiring a negative state.

EXPERIMENT VIII.

When the air is not too dry, or when the electrometer has been kept in a damp place, let the gold leaf be made to diverge by holding excited sealing wax near it, and let it continue thus diverging about
half

half a minute, then suddenly remove the sealing-wax and the gold leaf will first collapse, and then open with a contrary state of electricity. This I supposed wou'd have explained the positive cap above-mentioned: but when a ball of metal was insulated in dry weather by a warm tube of glass cover'd with sealing wax, it became quickly and strongly positive when the chalk was blown upon it within six inches.

EXPERIMENT IX.

A piece of chalk drawn over a brush so as to cause a cloud of powder to pass over the cap of the electrometer, produces a negative repulsion of the gold leaf, but without communicating a negative state of electricity.

EXPERIMENT X.

Powder'd chalk laid upon a metal plate placed upon the cap and blown off with the mouth or bellows, electrifies it permanently positive.

EXPERIMENT XI.

If a brush be placed upon the cap, and whilst held with one hand the brush be rubbed with a piece of chalk till a considerable cloud of powder be raised, and then the hand removed, as the cloud disperses the gold leaf will diverge positively. Or if the cap of the electrometer be touched by one person whilst another projects a cloud of powder'd chalk, the same effect will take place.

In

In this experiment a positive state is caused by the influence of the negative cloud.

EXPERIMENT XII.

Powder'd chalk falling from one plate to another placed upon the electrometer, electrifies it negatively.

EXPERIMENT XIII.

A book was chalked upon the edge and suddenly clapped together, powder'd chalk was projected from a goose wing, and the electrometer was introduced into the dust raised from the road by travellers, all which electrified it negatively: but when dust was struck up with a stick very near the electrometer it became positive, which agrees with exp. 1 and 2.

EXPERIMENT XIV.

Wheat, flour, oat-meal, and minium produce in every case positive electricity, where chalk and all other powders yet tried are negative; such are red and yellow okre, rozin, coal ashes, powder'd crocus metallorum, aurum mosaicum, black lead, lamp black, powder'd quick lime, umber, Spanish brown, powder'd sulphur, flour of sulphur, iron filings, rust of iron, sand. Also powders made from dried decoction of dyers woods as well as metallic calces, on the supposition of their similarity to flour or minium and other powders not registered, but none of these last were positive.

EXP.

EXPERIMENT XV.

The inside of the bellows pipe was moistened, but this did not alter the electricity of the powders blown thro', therefore its excitation does not appear to depend upon friction in the pipe.

EXPERIMENT XVI.

Air alone blown upon the cap does not electrify it, nor if blown thro' a hole made in a lump of chalk, whence it is not likely that the electricity is excited by friction against the air.

EXPERIMENT XVII.

A lump of chalk was insulated and rubbed upon a brush fasten'd to the cap of the electrometer, in this case both the chalk and brush were positive, and the ascending cloud of powder negative. Hence probably the excitation of the powder is not occasioned by the friction of the chalk against the brush, since the states of the lump and brush were not contrary.

EXPERIMENT XVIII.

Equal Measures and equal weights of powder'd chalk and wheat flour were mixed and projected from a brush, and the electricity of the chalk prevailed.

EXPERIMENT XIX.

Scales of iron were let fall from a plate a considerable height above the electrometer, which caused a cloud of dust to arise from the lower plate, this lower plate was therefore electrified positively, contrary

trary to the state it acquired by sifting the powder or letting it fall more gently.

EXPERIMENT XX.

A lighted candle placed upon the electrometer very much increases its sensibility, and is peculiarly useful in collecting atmospheric electricity: but if the communicated electricity is not constantly supplied, it will also soon dissipate its charge in the air.

EXPERIMENT XXI.

A small tube of glass cover'd with sealing wax was slightly excited, and tho' by the influence of its atmosphere it caused the gold leaf to diverge considerably wide, it did not communicate its electricity even when brought so near as to touch the cap; but when a candle was placed upon the electrometer, the electricity was communicated at the distance of twelve inches or more, and when strongly excited it caused a very sensible divergency at the distance of six feet.

EXPERIMENT XXII.

The electrometer with its candle was carried into a room just swept, and the dust diffused in the air caused a very sensible negative repulsion of the gold leaf.

EXPERIMENT XXIII.

The electrometer with its candle was carried thro' a room adjoining to that wherein the electrical machine had been turned for some time before, (the door

door between the Rooms having been left open,) and the air was found very sensibly electrified. The fluid being diffused thro' the air of both rooms.

EXPERIMENT XXIV.

Take a quantity of powder'd chalk, and also a quantity of wheat flour, and put alternately the chalk and flour into the bellows, and blow the powder into the air a few times. It is then easy for another person bringing the electrometer with its candle into the room, to discover whether the chalk or flour was used, the chalk being negative and the flour positive. In like manner if chalk and flour be projected on different sides of a room it may be discovered where the chalk and where the flour were used, or if they were mixed it will shew which prevails.

EXPERIMENT XXV.

No sensible electricity was produced by projecting water, salt, powder'd nitre, or allum, nor by smoke, flame, or explosions of gunpowder.

EXPERIMENT XXVI.

If the small end of a tobacco pipe be made red hot, and the pipe be fixed in a cloven stick, so that the stick may be easily placed in a small hole in the cap of the electrometer, in such a manner that the pipe may be directed towards another electrometer placed about four inches from the end of the pipe, upon putting some water into the pipe head, the
steam

steam will suddenly issue out of the small end, and electrify the first electrometer negatively, and the second positively.

EXPERIMENT XXVII.

Spirit of wine, and ether, were tried with the hot tobacco pipe, and their electricity did not differ from water, but they required less heat. Oil and vitriolic acid produced smoke which was not electrified.

EXPERIMENT XXVIII.

Let a cullender or tin funnel be suspended by silk, and put some hot coals in it. Upon throwing water on the coals the ascending vapour will be found electrified positively, and the drops of water falling thro' upon the electrometer will be electrified negatively: but if a second or third quantity of water be poured thro', the drops will sometimes become positive, as will be found more fully tried in another section.

EXPERIMENT XXIX.

Positive electricity is produced by blowing with one's mouth thro' a red hot tobacco pipe upon the cap of the electrometer, by the rarefaction of moisture contained in such air: but dry air blown thro' from clean dry bellows does not electrify it.

EXPERIMENT XXX.

Vapour of water was drawn into the valve of the bellows and blown upon the electrometer thro' the
iron

iron pipe, yet its positive electricity was not destroyed by thus passing thro' the bellows.

EXPERIMENT XXXI.

If a small lantern with a candle in it be placed upon the cap of the electrometer, and exposed to the air in an open place, or not too near high buildings, or trees, it seldom fails to render the atmospheric electricity very sensible.

EXPERIMENT XXXII.

The electrometer was carried into the middle of a field when the weather was clear and frosty, and a small lantern placed upon it, caused the gold leaf to stand open with positive electricity about an inch wide, and when carried up a mount about six feet higher the gold leaf struck the sides; but it gradually collapsed as it came near trees or houses.

EXPERIMENT XXXIII.

A vessel of water was placed upon an insulating stool in the open air, when the weather was dry and clear, then standing upon the same stool I spouted water as high as I cou'd with a small syringe about six times, then upon touching the cap of the electrometer with my finger, the gold leaf opened positively; the atmospheric electricity from a higher stratum of air having charged my body thro' the stream of water.

EXP.

EXPERIMENT XXXIV.

Red hot glass was brought very near the electrometer and the focus of a concave mirror made to fall upon the cap, neither of which hastened the dissipation of its electricity. Red hot iron draws it off, but not so far as flame.

EXPERIMENT XXXV.

An iron mortar was placed upon the electrometer and red hot cinders were dropped into it whilst electrified positively or negatively, but this did not diminish the divergency of the gold leaf. Bodies of equal surface but different in mass, when placed in the same circumstances are equally charged with electricity, according to the experiments of M. Achard, therefore various substances may be introduced into the mortar or other hollow vessel placed upon the cap of the electrometer, without adding to the quantity of electrified surface, which may be useful in trying various chemico-electrical experiments.

EXPERIMENT XXXVI.

If the electrometer be charged with a small quantity of electricity, and the sharpest pointed needle or edge of a razor be brought within the least visible distance towards the cap, it will not draw off its electricity, but flame draws it off at a considerable distance.

This experiment shews that sharp points or edges need not be avoided in the construction of this instrument, or of the doubler, or atmospheric apparatus

status described in the following sections, and that a flame is better than a pointed wire for the purpose of collecting atmospheric electricity.

EXPERIMENT XXXVII.

A very light pith ball was put upon the end of a very small wire, and the wire was suspended by a ring to the prime conductor of the electrical machine; also a wire of the same length, but without any pith ball, was suspended in a similar manner, and both were repelled by the electricity communicated to the conductor; but the wire with the pith ball descended first, which also shews that it is more necessary to make the electrometer light than to avoid points and edges.

EXPERIMENT XXXVIII.

A small pin was fasten'd upon the end of a stick of sealing wax and charged with electricity, which was communicated from the pin to a metallic insulated conductor, fifteen inches in diameter, and seven feet long, whose surface was therefore prodigiously larger than that of the pin, yet its electricity caused a very sensible divergency of the gold leaf. This not only shews the sensibility of this electrometer; but assists our conception of the amazing divisibility and elasticity of this wonderful fluid.

C

SECTION

[A description of the gold leaf electrometer and most of the above experiments, are printed in the philosophical Transactions for the year 1787.]



SECTION III.

New experiments with M. Lichtenburg's large electrophorus.

THE following experiments are intended as improvements on M. Lichtenburg's beautiful configurations, first made on a resinous electrophorus by drawing over it the knob of a charged phial, and render'd visible by sifting powder'd rosin over the plate, which falling so differently according to the circumstances in which the experiment is made, exhibits the diffusion of electricity in a very pleasing manner.

My first electrophorus was a glass plate fifteen inches square, cover'd on one side with a thin resinous black coating, with tinfoil pasted on the other side; for if the side opposite to the resinous one be not a conductor, the electrical fluid will not be easily diffused over it. Glass was used that the electricity might not be so liable to pass thro' the small holes and blistered places which cannot well be avoided if the resinous substance be thinly spread upon wood or metal.

As powder'd rosin projected from a brush is negatively electrified, there appeared no doubt but that chalk and other powders, which by the same means are negatively electrified, would answer as well or better; such powders were therefore tried and found to succeed remarkably well.

EXP.

EXPERIMENT I.

The plate was suspended by a loop against a wall that the groffer part of the powder might fall to the ground, and no more adhere to the plate than was attracted by the electricity diffused thereon. A small phial was charged very weakly by one revolution of the electrical machine, and after its knob had been drawn over the refinous plate, a cloud of chalk was projected by rubbing the lump upon a brush near the electrified surface of the plate, this produced a plain white line without any ramifications.

EXPERIMENT II.

When the phial was charged by three revolutions of the machine, ramifications appeared upon the plate at a considerable distance from each other.

EXPERIMENT III.

Five or six revolutions caused the electrical fluid to spread upon the plate in ramifications very near each other. Close to each branch a small space was left uncover'd with powder, forming a kind of shade to the figure. Beyond this shade the powder lay smooth, softening off externally.

EXPERIMENT IV.

With a very strong charge the ramifications were close and broad, resembling white feathers with a very broad shade.

EXPERIMENT V.

A large jar was charged as full as it wou'd hold and its knob drawn over the resinous plate, the middle of the figure was about an inch broad, and mostly plain and white, the shades were now more conspicuous than the branches, and dark irregular streaks intersected the distant white space.

EXPERIMENT VI.

When a bottle with a large wooden knob in it was highly charged, and its knob carried at the distance of an inch from the plate in a direction across it, the figure produced had no ramifications, but several cloudy white streaks appeared; these streaks vary their figure every time the experiment is tried.

EXPERIMENT VII.

When a figure was made upon the plate by drawing with a moist finger, and the moisture touched with the knob of the charged phial, the ramifications darted from the sides of the figure in a perpendicular direction; whereas the ramifications made by sliding the knob over the plate issued from the middle of the figure, sloping like the branches of a tree. The reason of this difference is plainly that in the first case each ramification is made at the same time, and in the latter the first branch repels that which is made after it, and thus prevents it from darting perpendicularly.

EXP.

EXPERIMENT VIII.

A small wire was laid upon the plate and an electrical shock made to pass thro' the wire, which was then thrown off without being touched; in this case, when the chalk was projected, the ramifications appeared very distinct and long but not shaded, and their direction was perpendicular to the figure. A moderate charge produced longer ramifications than a very strong one.

EXPERIMENT IX.

A circular brass plate with an insulating handle was placed upon the resinous plate, and a spark from the charged bottle was communicated to the brass plate which was then taken off by its insulating handle, and chalk projected, which produced a very regular circle of ramifications about four inches long, proceeding from the circumference of the space cover'd by the brass plate, and within the circle were a number of irregular figures somewhat like stars. A shock made to pass thro' the same plate generally produced more distinct ramifications, and sometimes without any stars within the circle; and if the brass plate was drawn along towards the edge of the electrophorus whilst touched with the knob of the phial a very beautiful figure was produced.

EXPERIMENT X.

The resinous plate was fastened to the top of the pillar which supports and insulates the cushion of the

electrical machine, and whilst the wheel was turning a brass knob was drawn over the plate, which produced very large and fine ramifications. A point drawn over, produced a figure very much resembling a white ostrich feather.

EXPERIMENT XI.

The plate remaining on the pillar as in the last experiment, a candle was brought very near the middle and immediately again removed. When chalk was projected, a circular space about twelve inches diameter was cover'd with powder, having a dark shade round it, beyond which the powder fell more thinly.

EXPERIMENT XII.

The plate was fastened to the prime conductor, and when the candle had been presented towards the middle as before, the chalk fell mostly on the outside of a circle of the same dimension.

EXPERIMENT XIII.

The phial was charged weakly negative and drawn over the plate which produced a plain line, but with chalk it was often black upon a white ground, contrary to the positive line. With wheat flower the line was as white as the positive one. Projected chalk being negative, and wheat flower positive, they wou'd always be only attracted by those figures whose electricity is contrary, but there is reason to believe that some of the projected powder
is

is either not electrified or possesses a state contrary to the rest, and therefore falls into the figure, but the difference of the powders is very conspicuous.

EXPERIMENT XIV.

The phial was charged strongly negative, and drawn over the plate. The figure was not ramified but consisted of a number of roundish spots, the largest about the size of a pea, with smaller spots between the large ones, the figure was shaded, and the space beyond cover'd with powder as in the positive experiments.

EXPERIMENT XV.

A phial strongly and negatively charged was drawn over the plate, and afterwards a pointed wire held in the hand only, was drawn over the same figure, then chalk was projected, which produced a beautiful ramified figure in the middle of the negative one.

EXPERIMENT XVI.

A conical tin funnel was placed with its base on the middle of the resinous plate, and a negative strong charge given by connecting the discharging rod with the under side of the plate, then a positive charge was given in the same manner, the funnel was thrown off and chalk projected, which produced very beautiful ramifications both within and on the outside of the circle.

EXPERIMENT XVII.

A phial was charged positively, and placed with its knob about half an inch distant from the middle of the plate. Whilst the phial stood in this situation chalk was projected, which adher'd smoothly to the knob of the phial, and to the surface of the plate for the space of about 9 inches diameter, every where cover'd except a very distinct circular spot about three inches distant from the knob, if the chalk was projected at several intervals, the successive projections, did not come up to the edge of the first circle, but fell round a larger circumference and not quite parallel to the first. A negative charge produced the same kind of spot. The cause of these spots was found to be electricity streaming thro' the air from the cork in the neck of the phial, for a wire placed in the cork near that which supported the knob alter'd the shape of the spot. The reason that it was left entirely without powder tho' occasioned by the communication of electricity, will appear in a subsequent experiment.

EXPERIMENT XVIII.

A knob of wood about an inch in diameter was placed upon the wire of a phial which was charged highly positive, and the knob drawn over the plate so as to touch the surface, this produced a beautiful figure, the middle of which was smoothly cover'd with chalk, and the sides finely ramified with shades.

EXP.

EXPERIMENT XIX.

A brass knob about three inches in diameter was placed upon the phial instead of the small one, and a ramified figure drawn with it upon the middle of the plate; then, before chalk was projected, the knob with the remaining charge was placed opposite to the figure at the distance of about half an inch. In this case the powder fell upon the knob, and on the outside of the figure, leaving its ramifications clean and distinct, but entirely without powder.

EXPERIMENT XX.

A small candle was insulated and its flame placed about an inch distant from the middle of the resinous plate, then the knob of a positively charged phial was suddenly brought to the flame, and both the flame and phial instantly taken away again. In this experiment when the chalk was projected a circular space about four inches in diameter was clean and free from powder, the rest of the plate was cover'd, except a great number of small circular or elliptical spots, which shews that the electrical fluid passed to the plate in detached balls like some atmospheric meteors, or the plate absorbed from the air a contrary state of electricity, which produced this appearance.

EXPERIMENT XXI.

If a positive figure be first drawn and then a negative one across it or v. v. when the powder is projected it is easy to distinguish which was first drawn,

drawn, the second appearing to cover the first, and when the positive figure is made last, the ramifications at the place of junction extend farther than the rest and are left without powder. But if both the strokes are positive or negative the first will appear to cover the second.

EXPERIMENT XXII.

If powders of different colours are mixed and projected over the figures, some of the colours will prevail on the middle and some on the outside, and especially if two figures whose electricity is contrary are made on the same plate, and most of all when both the electrical states of the figures and powders are contrary: for example, if minium whose electricity is strongly positive, and sulphur very strongly negative be pounded together, and then this mixed powder put into the bellows, and blown upon the contrarily electrified figures, the powders separate and the sulphur falls on the positive figure and the minium on the negative. This produces a very pleasing effect. I had often tried the experiment by projecting the powder from a brush: but the bellows do it much better, which last method was communicated to me by the Chevalier Landriani, who had seen it tried in Italy.

EXPERIMENT XXIII.

In some of the above experiments, when the resinous plate was positively electrified by drawing over it the knob of a charged phial, and chalk projected,

jected, the middle of the figure was covered with a plain streak of powder, or (if the charge was weaker) with beautiful white ramifications resembling flowers; round these ramifications there appeared a dark shade very exactly defined, whereon no powder fell, and next to this the powder fell smooth, diminishing in thickness towards the edge of the plate. On the first view of these appearances, I supposed that the positive electricity deposited upon the plate in the middle of the figure had render'd the shaded part of the space negative, and that therefore alternate spaces were positive and negative: but upon placing a wire in the cap of my electrometer, and drawing it over the plate in various directions, and sometimes covering different parts of the figure whilst others were tried I could never discover any signs of a negative state of electricity. The whole plate appeared positive, its intensity diminishing from the middle of the figure.

EXPERIMENT XXIV.

Not perfectly convinced of the entire positive state of the electrified plate by examining with the electrometer, I cemented a wire to the end of a glass tube covered with sealing wax, in such manner that the two ends extended each way like the points of a pair of compasses, then taking hold of the glass tube, I placed one end of the wire in the middle of a positive figure, and the other end upon a clean part of the plate, and drew the wire in the direction of the figure, keeping the first point in
the

the middle. Upon projecting chalk where the point had touched the clean part of the plate, shaded ramifications appeared which plainly shewed the middle of the figure to be strongly positive, as might be expected.

EXPERIMENT XXV.

A positive figure being drawn as above, the white part in the middle was carefully wiped off with my finger, so as to discharge its electricity, then the wire was placed with one point in the shaded space and drawn along the figure. Upon projecting chalk over the clean part of the plate positive ramifications were produced as before, but much weaker.

EXPERIMENT XXVI.

The white ramifications and shades were both wiped off, and the wire placed near the edge of the smooth white space, and with the other point on the clean part of the plate, and upon projecting chalk there was no figure produced : but if the wire was drawn in the same manner without wiping off the shaded part, a white line appeared with very few points like thorns, which sufficiently proved that it was weakly positive ; and hence it appears that it was the natural electricity of the plate disposed to attract powder by the influence of that which was communicated in the figure.

EXP.

EXPERIMENT XXVII.

The white ramifications in the middle of the figure were wiped off and then more chalk projected upon the shaded part which caused the ramified points to extend farther, and by wiping off still more and projecting chalk again, almost the whole of the shaded part was filled, which proves that this last space is left uncover'd, because the stronger electricity in the middle of the figure attracts all the powder which might otherwise fall in that space. And in many other experiments it is found that various parts of the same plate will be filled with powder or left clean, where the same state of electricity, but of different degrees of intensity, has been communicated, particularly exp. 3, 4, 5, 17, 18, and 19.

EXPERIMENT XXVIII.

Glass plates were cover'd with red or black sealing wax, and figures drawn upon the wax, then powder'd sealing wax, or other powders which wou'd not lose their colour by heating, were projected upon a plate of the opposite colour, and by holding the plates before a fire or over a candle till the surface was softened, the figures were indelibly fixed.

EXPERIMENT XXIX.

I have tried to take off the figures upon paper in various ways, and first projected lamp black, ivory black, powder'd rotten stone, vermilion, and many other powders, sometimes mixing them with
gum

gum arabic, and then laying over the plate a paper softened in water, with or without gum arabic dissolved in it, and in some experiments the figures came off very well, especially with vermilion, but mostly failed. I then tried the dry'd extract of dyers woods, and succeeded very well. And since several of my friends have expressed their desire to be informed of the process, I will describe it as minutely as I can.

To make red figures, take a pound of rasped Brazil wood, put it into a kettle with as much water as will cover it or rather more; also put in about an ounce of gum arabic and a lump of allum about as big as a large nut, let it boil about two hours, or till the water is strongly coloured; strain off the extract into a broad dish, and set it in an iron oven, where it is to remain till all the water be evaporated, which with me was effected in about 12 hours; but this depends on the heat of the oven, which shou'd not be so hot as to endanger its burning. Sometimes I have boiled the strained extract till it was considerably inspissated before it was placed in the oven, that it might be sooner dry.

When it is quite dry but not burnt, scrape it out of the dish and grind it in a mortar till it be finely pulverized. In doing this it is proper to cover the mortar with a cloth having a hole thro' to prevent the powder from flying away and offending the nose, and also to do it out of doors if the weather be dry and calm, that the air may carry away the powder necessarily escaping, and which otherwise

wife is very disagreeable. When ground fine let it be sifted thro' muslin or a fine hair sieve, returning the coarser part into the mortar to be ground again. When the grinding and sifting are finished the powder is ready for use. The resinous plate I have mostly used was composed of five pounds of rosin, half a pound of bees wax, and two ounces of lamp-black, melted together and poured upon a board sixteen inches square, with ribs upon the edges at least half an inch high, to confine the composition whilst fluid, thus the resinous plate was half an inch thick, which is better than a thinner plate, the figures being more distinct. After the composition is cold, it will be found covered with small blisters, which may be taken out by holding the plate before the fire, till the surface be melted, then let it cool again, and upon holding it a second time to the fire, more blisters will appear; but by thus repeatedly heating and cooling the surface, it will at last become perfectly smooth. Some plates were made smaller and the resinous composition confined to the form of an ellipsis, a circle or escutcheon, by a rim of tin half an inch broad, and fixed upon a board.

The next thing to be done is to prepare the paper, which is to be soften'd in water, either by laying the pieces upon each other in a vessel of cold water, or first pouring a little hot water upon the bottom of a large dish, then laying upon it a piece of paper, so that one edge of the paper may lie over the edge of the dish, to remain dry, that it may afterwards be more conveniently taken up. Then
pour

pour more hot water upon its upper surface. Upon this place another piece in the same manner, again pouring on more water, and thus proceed till all the pieces are laid in. By using hot water the paper will be more softened in a few minutes than if it remains in cold water a whole day.

When the figures are to be made the resinous plate must lie horizontally whilst the electricity is communicated, if the experiment requires any thing to be placed upon the plate: but it is convenient afterwards to hang it up in a vertical position whilst the powder is projected, lest too much powder should fall where it is not required.

A little of the powder may be taken between a finger and thumb, and projected by drawing it over a brush, or which is better, a quantity of powder may be put into the bellows and blown towards the plate. When the figure is sufficiently covered with powder, let the plate be again laid horizontally upon a table, then take one of the softened papers out of the water by its dry edge, and lay it carefully between the leaves of a book, pressing the book together, and let it lie in this situation about half a minute. Then remove the paper to a dry place in the book, and press it again about the same time, which will generally be sufficient to take off the superfluous moisture. Then take up the paper by the two corners of its dry edge, and place the wet edge a little beyond the figure on the resinous plate lowering the rest of the piece gradually till it covers the figure without sliding, then lay over it a piece of
clean

clean dry paper, and prefs it gently, let it remain a short time, and then rub it cloſer to the plate with a cloth, or which is better, prefs it down by means of a wooden roller cover'd with cloth, taking care that the paper be not moved from its firſt poſition. When the paper is ſufficiently preſſed let it be taken up by its dry edge, and laid upon the ſurface of a veſſel of water with the printed ſide downwards, by this means the ſuperfluous powder will ſink in the water, and the figure will not be ſo liable afterwards to ſpread in the paper. After the paper has remain'd on the water during a few minutes, take it up and place it between the leaves of a book, removing it frequently to a dry place. If it be deſired that the paper ſhou'd be ſpeedily dry, let the book-leaves in which it is to be placed, be previouſly warmed, and by removing it to ſeveral places, it will be dry much ſooner than by holding it near a fire, and without drawing the paper crooked. By the above proceſs it is obvious that leather, callico, or linen, as well as paper, may be printed with theſe figures, and the effects of the diffuſion of electricity upon a refinous plate be exhibited to thoſe who have not leiſure or inclination to perform the experiments.

The atmospheric electricity with all its variations of intenſity, and changes from poſitive to negative are marked on a refinous plate by an ingenious machine of the Chevalier Landriani, which moves by a clock, and the figures made on the plate during his abſence will become viſible when powder is

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pro-

projected. These figures may therefore be taken off by this process, and the state of a day's electricity in Italy be transmitted to England.

EXPERIMENT XXX.

Mr. Wedgwood proposed to fix the figures by projecting fine powder'd enamel, after the electricity was diffused upon porcelain, and then to bake the plate or vessel (thus ornamented) in the usual way. This experiment was tried at his house, and the figures were very well fixed; but the weather being then unfavourable, they were not so beautiful as might be expected. I have since made the figures with more success, but had not the opportunity of fixing them.

In this way the ramifications and shades may be indelibly fixed and preserved, without any diminution of their beauty.

EXPERIMENT XXXI.

Another way of preserving the figures is to make a resinous plate of a proper shape to be framed and covered with glass. After the figure is made and the powder projected, it is necessary to hold the plate over a vessel of hot water, that by means of the steam its electricity may be gradually discharged, for if it be covered immediately, the powder will fly off to the glass. In one experiment I painted a glass black on one side, then cover'd the painted side with brass leaf, and after heating it in the sunshine till all the moisture was expelled, I made

made the figures upon the uncoated surface, cover'd it with another glass, and placed it in a frame. When glass is made very dry the figures will be as distinct and beautiful as those made upon a resinous plate; but it is necessary to perform the experiment in dry weather, and to take care that the glass and knob of the bottle, with which the figures are drawn, be sufficiently and equally heated, for if the knob be colder than the plate, moisture will be condensed and spoil the figure. In trying experiments with a glass plate, I observed that it was very difficult to deprive it of the electricity last communicated. I rubbed the surface with wet cloths, then rubbed water with my fingers upon the electrified parts, then dipped the plate in water, and after that held it over the flame of a candle, yet found that all these methods were insufficient, the figures might still be seen when the glass was dry, and chalk again projected. I then rubbed the glass with tallow, and cleaned it off with powder'd chalk, which succeeded better.

EXPERIMENT XXXII.

I placed the above described glass plate in the sunshine where it was kept hot, and dropped a little oil upon the middle, and upon touching the oil with a positively charged bottle, it flowed in very fine ramifications. I then touched another drop of oil with a negative bottle, which also caused it to flow in ramifications, which I cou'd not perceive to

differ from the positive ones, except that they did not extend quite so far.



EXPERIMENT XXXIII.

I rubbed a circular space in the middle of the glass plate with water, and touched it with a charged bottle, then projected chalk which cover'd the moist space with a plain smooth coating of chalk, I then dried it over the flame of a candle, which also discharged its electricity. On the middle of this white space I dropped some oil, and upon touching it with the charged bottle it shew'd its spreading ramifications more plainly than in the last experiment. Also this plain white space being touched with a positive bottle, (by chalk thrown off the surface) shews ramifications more distinctly filled with branches than those made upon clean glass or resin.

EXPERIMENT XXXIV.

The surface of a resinous plate was melted and powder'd rosin sifted upon it so as to make it very rough, this caused the figures to spread less than upon a smooth plate, so that the points of the ramifications came very near the edge without striking off.

EXPERIMENT XXXV.

A positive figure was drawn upon a resinous plate and chalk projected considerably longer than usual, and then on examining the figure there appeared
small

small ramified vegetations like those produced upon camphire by M. Moscati. Also negative figures with flour produced the same.

EXPERIMENT XXXVI.

The powders made from the decoction of woods described in exp. 29. are very troublesome when projected in the open air, and a considerable quantity is lost in every experiment. I therefore contrived to project the powder by means of a circular brush inclosed in a box. Its lid A. plate 3d. fig. 1. is sixteen inches square, with edges about an inch and a half deep. The resinous composition is poured within these edges of the lid to the depth of half an inch. The sides of the box as far as the perpendicular part at B. are six inches deep; the sloping boards at C. ten inches. The circular box D. in which the circular brush is inclosed is six inches diameter, and three inches thick. A wire or small glass tube is put thro' the circular box at E. that the hairs of the brush when turned round by the handle F. may flirt against it and project the powder thro' an opening at C. and diffuse it into the air contained within the box, and thus the figures made on the resinous plate within the lid will attract the finest part of the powder, or that which is most strongly electrified with the contrary state to that of the figure, and the rest will fall down again. If the box contains too little powder it will be necessary to lean it on one side, and if there be a large quantity, the brush must be turned slowly lest it shou'd throw up too much. Smaller resinous

plates may be supported within the box by bars of wood placed across, and cover'd over with the lid whilst the powder is projected.

EXPERIMENT XXXVII.

That I might more conveniently draw a variety of figures as well as try the effects of a very small Leyden bottle, I made an electrical pen, by silvering the inside and gilding the outside of large thermometer tubes, from three to eight inches long, with and without bulbs, covering the ends with sealing wax. In one end was fixed a blunt needle connected with the internal metallic surface. Some were coated on the outside with tin foil, and a wire served for the internal coating. Whilst drawing with them, a charged bottle stands ready to supply electricity by touching its knob with the point of the needle. Small or large knobs, camel hair pencils, thistle down, and other substances occasionally fixed on the point, produce different effects, and with the smallest pen lines may be drawn as fine as can be made with ink.

EXPERIMENT XXXVIII.

For the purpose of making circles, spiral lines, volutes, &c. an iron pin is fixed to the conducting side of the lid of the projecting box at G. plate 3 fig. 1; and when electricity is to be communicated to the resinous surface, the pin is placed in a hole made in the table, and the plate whirled round, whilst it is touched with the knob of a charged bottle,

bottle, or pen described above, so as to produce the required figure.

EXPERIMENT XXXIX.

The figure mentioned at the end of exp. 9th, made by drawing the brass plate towards the edge of the electrophorus, by its insulating handle whilst the plate was touched by the knob of a charged bottle, somewhat resembles the picture of a comet; but in the tail I frequently observed that a circular or elliptical space was left without powder, which may reasonably be attributed to the absorption of a contrary state of electricity from the air, which weakens the intensity of the charge diffused in that space; see plate 3, fig. 6. An electrified cloud or stratum of air emits or absorbs balls of electrical fire called meteors or falling stars, to which this experiment may bear some resemblance.

EXPERIMENT XL.

A circular plate of wood 12 inches in diameter was covered with tin-foil, and furnished with an insulating handle, this plate had also three feet of glass about an inch long, cover'd with sealing wax. A resinous plate half an inch thick and of less diameter than the wooden plate, was laid upon a table, and the wooden plate placed over it, its feet standing upon the table on the outside of the resinous plate, so that the surface of the wooden plate stood about half an inch higher than the surface of the resinous plate. The knob of a charged bottle was

D 4

applied

applied to the wooden plate which was then removed. Upon projecting powder the surface of the resinous plate was covered with circular elliptical and irregular spots and rings. If the charge was weak there appeared only small round spots, but a strong charge produced rings broader or narrower according to the state of the air and strength of the charge. After touching the wooden plate with a positive bottle, I sometimes removed the plate a little from its first position, and then touched it with a negative bottle, and instead of a single powder, the mixture of minium and sulphur were blown upon the plate, as in exp. 22, which distinguished the positive and negative rings by the yellow and red colours.

Upon examining these rings by the method described in exp. 24, it appeared that the whole space included within the rings was covered with electricity; and yet the powder was only attracted by the edges of the space, probably because the intensity of the middle is diminished by the equally surrounding repulsion of the sides.

The circles of green grass called fairy rings are with great probability attributed to the effects of lightning. See Dr. Priestley's Hist. of Electricity, vol. 2. page 274, of which this experiment may be esteemed a tolerable artificial imitation.

SECTION IV.

*Experiments in which electricity is condensed or rarified
by the evaporation of water from various substances.*

IN a treatise on electricity by M. l'Abbe Haüy, I find that since M. Volta's discovery of electricity produced by evaporation of water from hot coals, Messrs. Lavoisier and De la Place have remarked, that bodies passing from a solid or fluid state into vapour, give unequivocal signs of positive or negative electricity. A large vessel containing a quantity of iron filings was insulated and connected with M. Volta's condenser. Three parts of water and one of vitriolic acid were poured upon the filings, which caused a brisk effervescence, and a rapid discharge of inflammable air, and in a few minutes the condenser became so strongly charged that it gave a very sensible spark, and by the electrometer it was found to be negative. The production of fixed and nitrous airs had the same effect. Also chafing dishes insulated and filled with lighted coal produced very clear signs of negative electricity after the combustion of the coal. It appears that in these experiments, the substances evaporated carry away from the vessels with which they are in contact, a part of their natural electricity. But when water was poured upon red hot iron pans the elec-

electricity was no more negative as in the former experiments, but decidedly positive. These experiments were communicated to the academy of sciences in the year 1781.

M. de Saussure has also tried many experiments of this kind by plunging hot iron and other metals in water, and pouring water into crucibles of iron, brass, copper, silver or porcelain. Sometimes he used distilled water, also spirit of wine and ether, and in these experiments the electricity was sometimes positive, sometimes negative, and sometimes neither.

M. de Saussure thinks that when the operation which converts the water into vapour, at the same time decomposes it, or the body with which it is in contact, it produces a new quantity of the electrical matter, and that the vessel used in the operation becomes positive, negative, or neither, according as the fluid produced is superior, inferior, or equal to that which is taken from the vessel by evaporation. An account of these curious experiments is contained in the second volume of M. de Saussure's travels over the Alps, page 227.

The gold leaf electrometer being well adapted to the performance of experiments of this kind, I was induced to repeat some of them with variations in hopes of new appearances. And since almost every substance in the whole chemical nomenclature may thus be subjected to the action of fire, and its affinity with electricity in a state of vapour examined,

ned, new facts may yet arise which will produce new theories, therefore the following experiments are placed in the order they were tried without regard to system.

EXPERIMENT I.

A basin of tinned iron about six inches wide at the bottom, and eight inches at the top, was placed upon the cap of a gold leaf electrometer. The bottom of the basin was cover'd with water about an inch deep. An iron chissel was heated red hot, and dropped into the water, one end being immersed and the other resting on the edge of the vessel. The gold leaf gradually open'd about an inch negatively, then closed and open'd positively, remaining positive to the end of the experiment. See plate 3. fig. 5.

EXPERIMENT II.

The chissel was heated more than in the last experiment, and the gold leaf struck the sides of the electrometer six times negatively, then it changed and stood at half an inch positive to the end.

EXPERIMENT III.

The chissel was again made very hot and it caused the gold leaf to strike often negatively, after which it closed, but never open'd positively.

EXP.

EXPERIMENT IV.

The chissel was heated very much by blowing the fire, and it caused the gold leaf to strike fourteen times negatively but no positive electricity appeared, this was repeated above twenty times without any production of positive electricity.

EXPERIMENT V.

Upon observing that the chissel was much calcined upon its surface, by being so frequently heated in the above experiment, I rubbed off the calx, and heated it again, and found that now it produced first negative and then positive electricity, as before; whence it appeared that its production of positive electricity depended upon the metallic state of the iron.

EXPERIMENT VI.

A large bar of copper and a piece of brass were heated red hot and plunged in the water, which also produced first negative and then positive electricity.

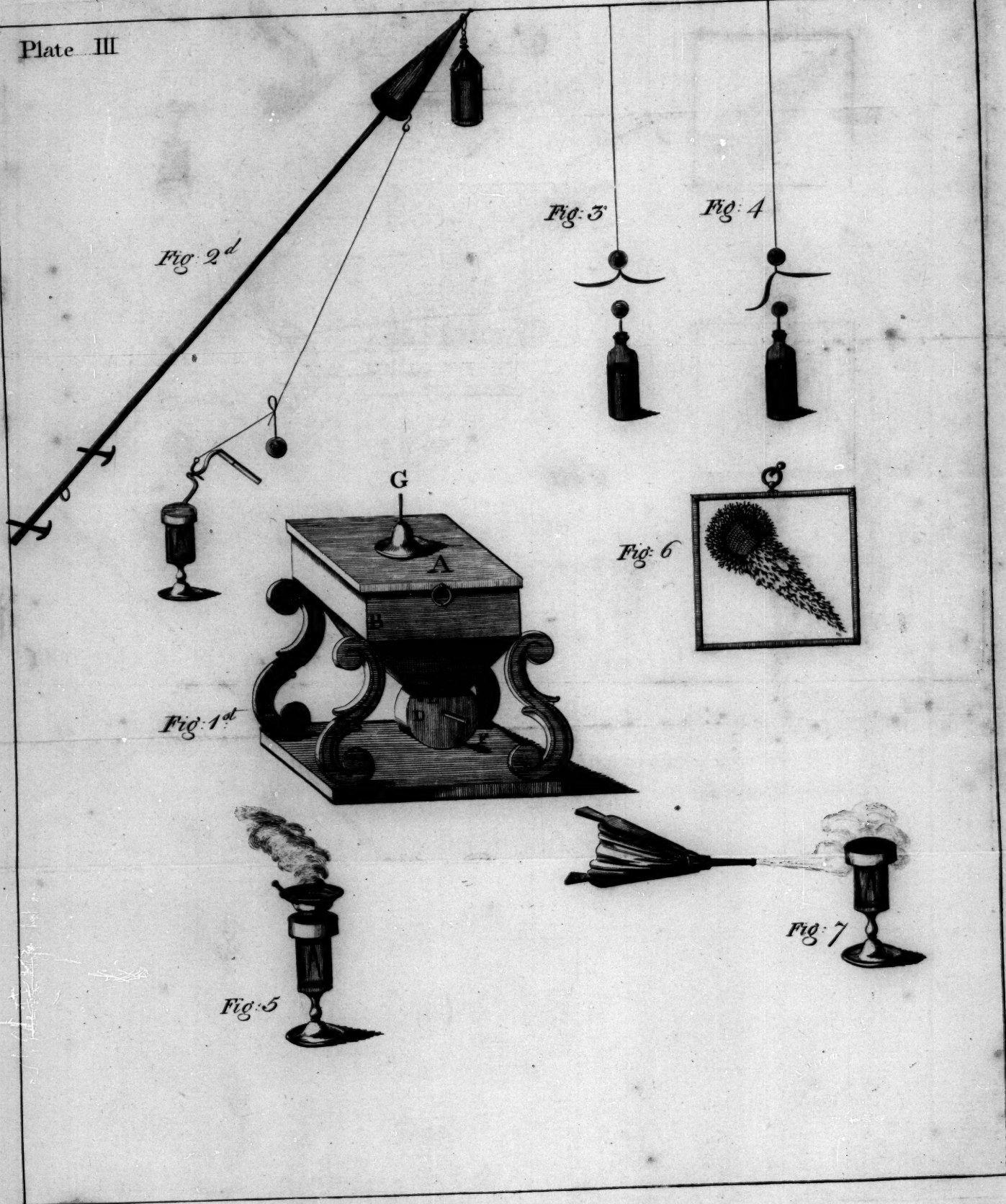
EXPERIMENT VII.

Melted lead was dropped into water contained in the basin as above, which gradually opened the gold leaf positively.

EXPERIMENT VIII.

Melted lead being dropped into a deep narrow vessel almost full of water did not electrify it, since
it

Plate III



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it emitted no vapour, it is therefore not the mere decomposition of the metal but the formation of a certain kind of vapour which excites electricity.

EXPERIMENT IX.

Boiling Mercury was dropped from an earthen crucible into a small quantity of water in a porcelain cup standing upon the cap of the electrometer which caused the gold leaf to open positively.

EXPERIMENT X.

Several thin pieces of bell metal were heated red hot and dropped into water, which caused a negative repulsion only.

EXPERIMENT XI.

An earthen unglazed flower pot was half filled with red hot cinders, then the other half was filled with chopped grass, which caused the gold leaf to open with positive electricity, and to continue striking the sides a considerable time. In the same manner were tried cabbage leaves, lettuces, turnip tops and roots, and chick weed, with the same results.

EXPERIMENT XII.

Turnings of dry ash wood were thrown upon the hot cinders as above, which smoked much without causing any repulsion of the gold leaf till water was added, which caused a strong positive electricity.

EXP.

EXPERIMENT XIII.

Dry hay was burnt in the flower pot, as above, which produced no electricity till water was added, and then it became strongly positive.

EXPERIMENT XIV.

The flower pot was placed upon the electrometer with red hot cinders alone, and water was dropped into the middle, which open'd the gold leaf negatively; then more water open'd it positively. The cinders were renewed, and water dropped in the middle open'd the gold leaf negatively, then dropped near the side open'd it positively, again in the middle negatively.

EXPERIMENT XV.

Since the cinders became both positive and negative with water only, I repeated the above experiments on green and dry vegetables with a red hot earthen crucible, but without any difference in the result. A square piece of brick was first placed upon the electrometer, to prevent the heat from injuring it in this and all the subsequent experiments, in which red hot bodies were to be placed upon it.

EXPERIMENT XVI.

A spoonful of salt was thrown into the red hot crucible, which open'd the gold leaf negatively; a second quantity was thrown in, and it became positive.

EXP.

EXPERIMENT XVII.

The crucible being again heated two spoonfuls of salt were thrown in, which open'd the gold leaf positively; then water was dropped into the middle of the salt, which changed its electricity to negative; then more water dropped near the side of the crucible open'd the gold leaf positively; then again in the middle negatively.

EXPERIMENT XVIII.

Salt and water were mixed and dropped into the red hot crucible, which caused a strong negative repulsion; then after the water was evaporated more was dropped in the middle, which renewed the negative repulsion till the water was dropped near the side, when it became positive; this change from positive to negative was often repeated.

EXPERIMENT XIX.

A small quantity of salt was thrown into the red hot crucible, which caused the gold leaf to open negatively; then the salt remained till it was burnt black, and water being added caused a strong positive repulsion.

EXPERIMENT XX.

The vitriolic and nitrous acids were severally dropped upon red hot bricks, which open'd the gold leaf positively. The bricks were tried before and after the experiments with water, which caused a negative repulsion.

E X P.

EXPERIMENT XXI.

A large red hot cinder was placed upon the electrometer, and olive oil dropped upon it, producing a copious smoke, but no electricity, then water was added, which open'd the gold leaf negatively.

EXPERIMENT XXII.

Olive oil and water were shook together in a phial, and both poured upon a red hot piece of cast iron about an inch thick, 4 inches broad, and 5 inches long, which open'd the gold leaf strongly negative.

EXPERIMENT XXIII.

Vitriolic and nitrous acid were dropped upon the cast iron, which open'd the gold leaf positively.

EXPERIMENT XXIV.

Dry hay was placed upon the cast iron, and pressed down by a stone placed upon it till it was burnt black, then water was added, which open'd the gold leaf positively. The hay was then brushed off, and more water dropped upon the iron, which caused the gold leaf to open positively, till the surface was well cleaned and heated again, when it produced negative.

EXPERIMENT XXV.

An heap of wheat flour was placed upon the hot iron, which smoked without any electricity, till water was added, which open'd the gold leaf positively.

EXP.

EXPERIMENT XXVI.

Sand placed upon the hot iron, and water added, open'd the gold leaf negatively.

EXPERIMENT XXVII.

Lump sugar placed upon the hot iron produced no electricity till water was added to the burnt residuum, which open'd the gold leaf positively.

EXPERIMENT XXVIII.

Powder'd charcoal was placed upon the hot iron, and water dropped upon it, open'd the gold leaf positively : but when water was dropped upon a red hot piece of charcoal it caused a negative repulsion.

EXPERIMENT XXIX.

Red and white port wine dropped upon the hot iron produced negative repulsion when the iron was so hot as to produce no electricity with water alone, which was tried before and after the wine.

EXPERIMENT XXX.

Raspberry wine dropped upon the hot iron produced positive electricity. The raspberry wine and red port were alternately dropped upon the same iron five or six times successively, which changed the electricity from positive to negative each time. Also several other sweet wines were tried, which as well as sugar and water produced positive electricity.

E

EXP.

EXPERIMENT XXXI.

Fresh urine poured upon the hot iron produced strong positive electricity.

EXPERIMENT XXXII.

Milk poured upon the hot iron caused a strong negative repulsion, and even when water was added to the burnt residuum, except in some instances when it was burnt very black, it became weakly positive.

EXPERIMENT XXXIII.

Butter was burnt upon the hot iron, and water added caused a strong negative repulsion.

EXPERIMENT XXXIV.

Ale produced no electricity till water was added to the burnt residuum, which became positive.

EXPERIMENT XXXV.

Dry tea leaves were burnt upon the hot iron, and water added open'd the gold leaf positively, also black pepper and tobacco.

EXPERIMENT XXXVI.

Sope first burnt on the hot iron and then water added, also sope and water mixed produced a strong negative repulsion.

EXP.

EXPERIMENT XXXVII.

Tin-foil was placed upon the hot iron which soon melted, then water dropped upon it first open'd the gold leaf negatively, then weakly positive.

EXPERIMENT XXXVIII.

Alum burning on the hot iron produced no electricity till water was added to the burnt residuum, which caused a strong positive repulsion.

EXPERIMENT XXXIX.

Moist salt of tartar was thrown upon the hot iron which caused the gold leaf to open strongly negative, its vapours condensed so quick upon the tube used for trying the electricity, that it was with some difficulty that it cou'd be excited.

EXPERIMENT XL.

Saliva produced positive electricity. When water alone was producing negative repulsion, spitting upon it wou'd immediately change it to positive.

EXPERIMENT XLI.

Yeast was strongly positive, but not till water was added to the burnt residuum.

EXPERIMENT XLII.

Cotton and linen rags were burnt on the hot iron, and water added, produced a weak positive repulsion.

EXPERIMENT XLIII.

Sheep's wool, feathers, and hair, were burnt on the hot iron, and when a single drop of water was added, the gold leaf struck the sides of the electrometer positively.

EXPERIMENT XLIV.

Rasped horn and bone were burnt upon the hot iron, which produced positive electricity when water was added, but not near so strong as in the last experiment.

EXPERIMENT XLV.

Powder'd pit coal was placed upon the hot iron, which produced positive electricity upon the addition of water.

EXPERIMENT XLVI.

Fresh sheep's blood was dropped upon the hot iron, which produced positive electricity.

EXPERIMENT XLVII.

A hollow piece of bell metal about an inch thick, and three inches diameter, was cast on purpose to repeat these experiments upon, most of which were again tried, but with no remarkable difference, except that water produced negative electricity with more certainty. Upon the iron it was sometimes negative, sometimes positive, but mostly none at all; whereas on the bell metal it was almost always negative.

EXP.

EXPERIMENT XLVIII.

Vinegar produced no electricity when dropped upon the hot bell metal, till water was added to the burnt residuum, which caused a strong positive repulsion.

EXPERIMENT XLIX.

The bell metal was at last made too hot and therefore broke to pieces as it was taken out of the fire, I therefore again had recourse to cast iron, and for the sake of its holding fluid substances, I turned a cast metal weight so as to have a very smooth concave surface in the middle, and a concave rim near the edge, so that I cou'd place upon it several substances at once without mixing.

The lean part of a leg of veal was chopped small, and a small quantity placed upon the red hot cast iron, which caused the gold leaf to open positively, but after burning some time water was added, which changed its electricity.

EXPERIMENT L.

The fat of veal was burnt upon the hot iron, which produced no electricity till water was added, which caused a strong negative repulsion both before and after it was burnt black.

EXPERIMENT LI.

Nitre was put upon the hot iron, which melted without producing electricity; then water was dropped upon it, which exploded without producing

any electricity ; sometimes small globules of water floated a considerable time upon the melted nitre, and then suddenly exploded without ever producing any electrical repulsion or gradual evaporation, as is usual with other substances.

EXPERIMENT LI.

Bees wax produced strong negative electricity, with the addition of water.

EXPERIMENT LIII.

Verdegreafe with water produced very weak positive electricity.

EXPERIMENT LIV.

Powder'd antimony smoked much, and when water was added the gold leaf open'd negatively.

EXPERIMENT LV.

Carraway feeds dropped upon the hot iron caused a strong negative repulsion without the addition of water, also water added when they were burnt black open'd the electrometer negatively.

EXPERIMENT LVI.

Hemp seed thrown upon the hot iron caused a weak positive repulsion, but when water was added it became strongly positive.

EXPERIMENT LVII.

A tea spoonful of water was dropped into the
con-

concave hot iron which did not produce any repulsion, then some powder'd gum arabic was added which caused the gold leaf to diverge positively, then bees wax was also added which caused it to become negative.

EXPERIMENT LVIII.

These two last substances were dropped on the hot iron in the reversed order which first produced negative and then positive.

EXPERIMENT LIX.

Mustard seed was dropped upon the hot iron, which caused no repulsion till water was added to the burnt residuum, which open'd the gold leaf negatively.

EXPERIMENT LX.

Linseed produced no electricity till water was added to the black residuum, which open'd the electrometer weakly negative. The iron was then made hotter, and the addition of water produced positive.

EXPERIMENT LXI.

Canary seed also produced negative by the addition of water till it was burnt very black and then it became positive: also anise seed, and fennel seed, were like the canary.

EXPERIMENT LXII.

Burnt millet seed produced positive electricity with the addition of water.

EXPERIMENT LXIII.

Water added to burnt coriander and cummin seeds, produced negative electricity till the residuum had continued burning a long time, and then it became positive.

EXPERIMENT LXIV.

Hitherto the electricity of the apparatus, whence the vapours ascend, has been only examined. I now fastened a piece of paper upon a bent wire, which being placed in the cap of the electrometer hung over the hot iron, so that the vapours in ascending might pass over the paper, and shew whether this electrical state would in any instance be of the same kind observed in the vessel.

EXPERIMENT LXV.

The vapour of red port wine was tried as above and found positive, contrary to the state of the iron in exp. 29.

EXPERIMENT LXVI.

The vapour of raspberry wine was found to be negative contrary to the state of the iron in exp. 30. Also wine made from bilberries, and sugar and water mixed, produced negative vapours.

EXP.

EXPERIMENT LXVII.

The vapour of pure water was positive, but the addition of a small quantity of saliva changed it to negative.

EXPERIMENT LXVIII.

The vapour of raisin wine was first positive and then negative, and the reverse when the iron was examined.

EXPERIMENT LXIX.

As carraway seed produced negative electricity without the addition of water, and therefore without any visible vapour except a little smoke, the paper fixed upon the electrometer was several times placed at different distances above the hot iron, whilst the carraway seeds were burning, but no electricity appeared.

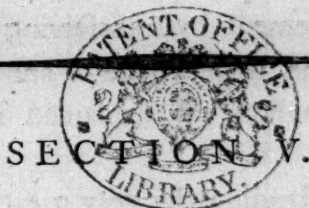
EXPERIMENT LXX.

The square brick which supported the hot iron was placed in the middle of an earthen plate full of water, and standing upon the electrometer, then the hot iron being laid upon the brick and out of the reach of the water, wool was burnt upon it, and a spoonful of water added; lastly, the whole was cover'd with a glass jar with its mouth immersed in the water that the vapour might not escape without touching the water; in this experiment no electricity appeared.

From

From these experiments it appears that various mineral, vegetable, and animal substances when evaporated, cause a positive or negative divergency of the electrometer, and it was remarked in the beginning of this section that M. de Saussure attributed these effects to the generation of a new quantity of the electrical fluid: but since the state of the electricity of the ascending vapour is contrary to that of the insulated vessel whence it rises, it now seems more probable that the vapour thus produced acquires its positive or negative state, because its affinity with the electrical fluid is greater or less than that of the vessel, and that when a particle of vapour is but just in contact with the surface whence it rises, its capacity to become positive or negative is much greater than when it is entirely surrounded with air; and thus if the vapour becomes positive by absorbing electricity from the vessel, the vessel will become negative and v. v. without the necessity of supposing a new quantity of the fluid to be generated in this process.

SECT.



A description of a doubler of electricity by which a very small quantity of electricity may be augmented till it becomes sensible by common electrometers, or visible in sparks.

THE great importance of a machine for the purpose of detecting very small quantities of electricity has occurred to many electricians, as by such an assistant it is to be hoped that important discoveries may be made in the atmospheric electricity as well as in chemical experiments, wherein it may be suspected that electricity is combined with other substances. And many curious and well contrived electrometers have been made from the time that Mr. Canton first used his pith balls, till Mr. Cavallo substituted fine wires and balls suspended in a glass: but these as well as my gold leaf electrometer were incapable of discovering such very small communications of electricity as were made sensible by Mr. Volta's condenser, which by means of a thin coated electric is capable of receiving a much greater quantity of the electrical fluid than a common insulated conductor of the same dimension, which fluid becomes sensible by separating the positive and negative sides of the charged plate. On this ingenious contrivance Mr. Cavallo made a very considerable

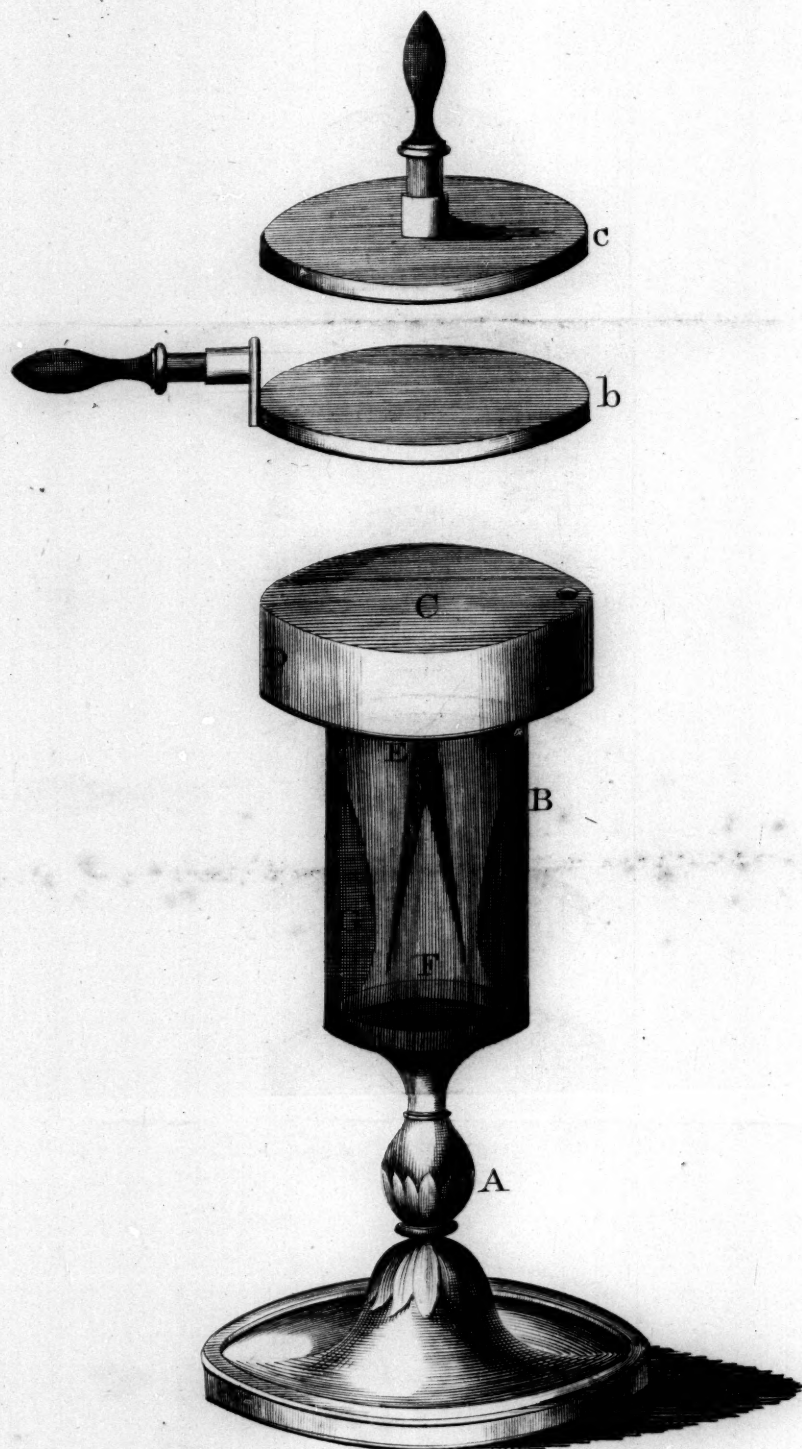
derable improvement by transferring the electricity contained in the upper plate to another condenser of smaller dimension, as explained in the *philos. trans.* vol. 72.

Yet notwithstanding the very great sensibility of this apparatus, atmospheric electricity cannot always be discovered by it, for instance, when the negative state of falling rain is nearly equal to the positive state of the air thro' which it falls.

The following instrument (which from its peculiar manner of augmenting small quantities of electricity I have named the electrical doubler) will render much smaller quantities of electricity sensible than the above-mentioned double condenser, unless the first condenser exceeds the dimension of the second as much as shall render its power equal to a given number of operations of the doubler, and so far they may be consider'd as the same instrument, for the doubler is only a condenser multiplying its capacity in geometrical progression: but this capacity augments so quick that a double condenser equal to its power at the twentieth operation must be 40 yards in diameter if the doubler and smaller condenser be only 2 inches.

The sensibility of the doubler was evinced by an electrico-meteorological diary kept for above a month, during which time I never failed to collect and distinguish atmospheric electricity. This diary I undertook at the request of my friend, Dr. Darwin, who hoped some important atmospheric discoveries might be made thereby, and which accompanied

Plate I



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accompanied my description of the doubler presented to the Royal Society by the Dean of Lincoln, and printed in the *philos. trans.* vol. 77.

This instrument in its first and simplest construction consists of two polished brass plates with insulating handles. The handle of one is fixed on the side of the plate, and the other on the middle, and standing perpendicularly, see plate 1st.

The plates are varnished on the under side, and the handles are made of mahogany, and fixed to the plates by insulating nuts of glass cover'd with sealing wax.

The method of collecting electricity from the atmosphere, and continually augmenting it till it became sensible, was thus performed.

In dry weather I carried into the open air a lighted torch not liable to be easily blown out, or a small lantern with a lighted candle in it, to the bottom of which was fixed by means of a socket an insulating handle of glass cover'd with sealing wax. In the other hand was carried a coated phial. Then elevating the flame a little higher than my head I applied it to the knob of the phial, holding it in this situation about half a minute. By this means I have found that more electricity may be collected than by an exploring wire insulated and fixed to the top of a church steeple, as practised by F. Beccaria. Having thus collected a sufficient charge I return'd into the house and applied the knob of the phial to the cap of the gold leaf electrometer, upon which I placed the plate (b) touching it with the forefinger stretched

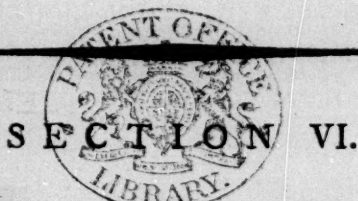
stretched over the insulating nut ; by this operation the electricity contained in the phial spreads upon the cap which serves as a condensing plate, and electrifies the plate (b) contrarily, because it is connected with the earth, and the varnish is interposed as a charged electric. The phial being now removed and the forefinger lifted up, the plate (b) is separated from the cap, and the plate (c) placed upon its upper side and touched by stretching a finger over the nut of its insulating handle, this last plate is then electrified contrary to (b) and the finger being removed, and the plate (c) separated from (b) it will be evident to electricians that the electricity of the cap and that of the plate (c) will be of the same kind, and nearly of equal quantity, so that the original charge is now doubled.

I then apply the edge of the plate (c) to the side of the cap, and placing (b) as before, and touching it again, the electricity of (c) as well as that of the cap, both act upon the plate (b) and the intensity of its contrary electricity becomes equal to both ; then removing (c) which comes away unelectrified ; I take off my forefingers from (b) and lift it up, and placing (c) upon it I proceed as before, thus continuing to repeat this doubling process till the gold leaf diverges sufficiently to examine the quality of its electricity ; or if the gold leaf be first taken out, the process may be continued till sparks appear.

In rainy weather the knob of the phial was applied to the insulating handle of an umbrella, or to

a torch carried under it, and in this manner I continued to examine atmospheric electricity, till I constructed a more convenient apparatus described in section the eighth.

To prove that the electricity is doubled, it may be observed that the gold leaf opens to about twice the distance at each operation, and the application of the plate (c) to the side of the cap, or to a wire placed in it, does not diminish the divergency of the gold leaf tho' in this situation their electricity is diffused over double the quantity of surface, and admitting that the charge is doubled every time, which is not far from the truth whilst the intensity is weak, the twentieth operation will augment the first quantity of electricity above 500,000 times, and this process even with a doubler in its original and most imperfect state may be performed in less time than a minute.



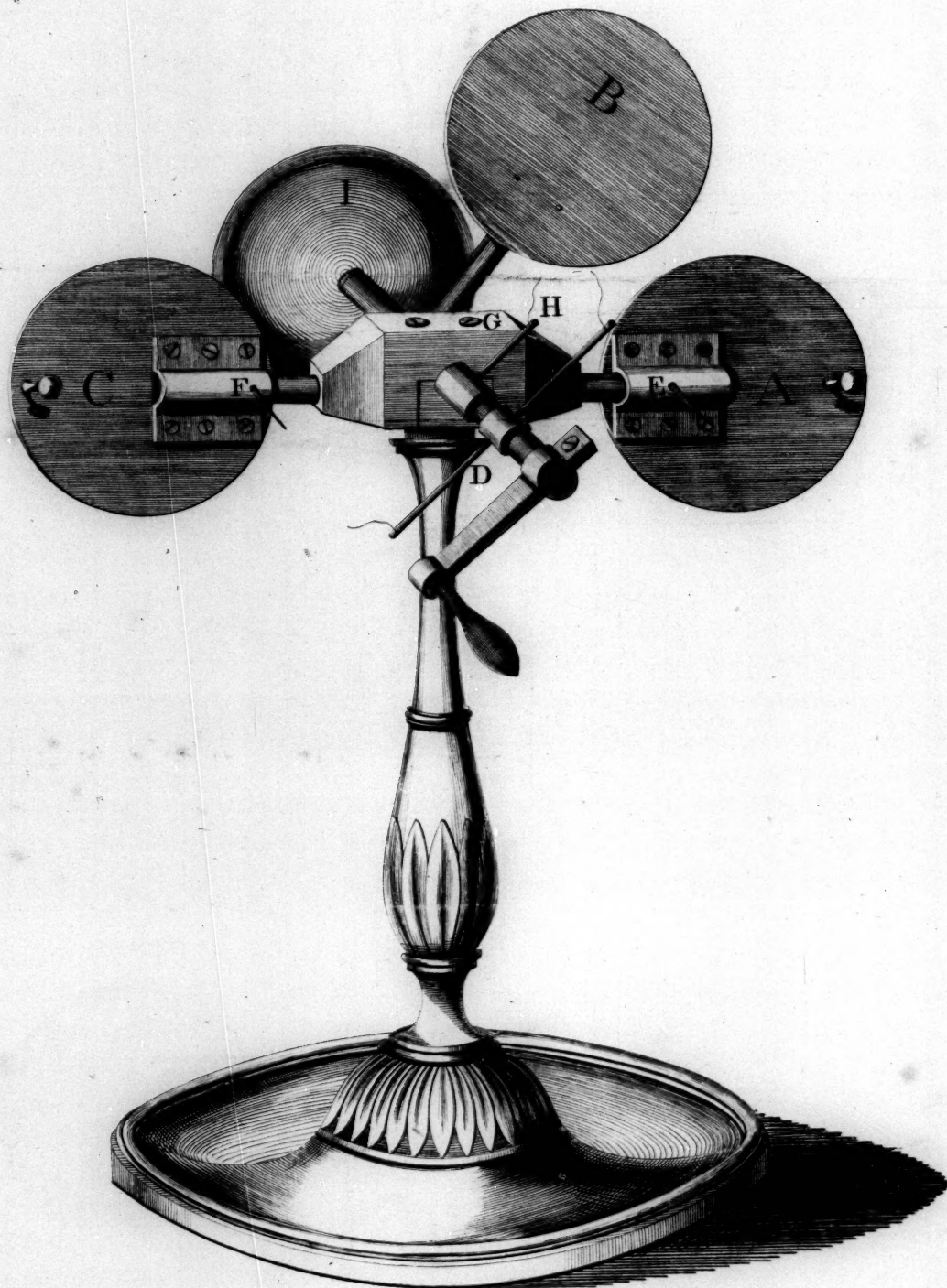
SECTION VI.

Improvements of the electrical doubler, with experiments made to discover the causes and obviate the inconvenience of its adhering or spontaneous electricity.

SOME time after the construction of my doubler of electricity described in the philos. trans. vol. 77, and in the above section, I found that on performing the doubling process a sufficient number of times, it always produced electricity without previous communication, even after every method likely to prevent it had been tried; yet this impediment was not so great as to render the instrument useless, for the adherent or spontaneous electricity in the beginning of the process, when the instrument was cautiously used, being very small, was easily overcome by that which was communicated in atmospheric experiments, and in case of doubt the atmospheric electricity was distinguishable by applying the bottle which collected it, to the two first plates alternately as mention'd in my description of the instrument.

However to deprive the doubler entirely of its adherent or spontaneous electricity, was thought a desirable circumstance, as its sensibility wou'd then be much greater, and consequently it might with
more

Plate II



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more certainty be applied to the discovery of new electrical facts, and which in this and the next section I hope will be sufficiently proved.

Dr. Darwin, at the desire of Lord G. A. Cavendish, made the first attempt with two plates moving between two others by a lever, so as to bring them exactly to the same position in each operation. This contrivance he soon improved by another instrument in which the plates stood vertically and moved by rack work in a direction exactly parallel to each other. With this I tried whether the plates wou'd act without any resinous substance, and found that the interposed air was a good substitute, and hoped that now since it was not necessary to varnish the plates, nor bring them into contact, the spontaneous electricity supposed to arise from the accidental friction of the plates wou'd not be produced. This instrument was sent to Mr. Partington, and the improvement of placing the plates near together without varnish was soon after mention'd to him in a letter.

That I might accurately try whether the instrument wou'd be improved by this omission of varnish, I made a doubler which consisted of three plates standing vertical and parallel, the middle plate sliding backwards and forwards between the two others. The connection between the two external plates was performed by lifting up the sliding handle, and the distance of approach was adjusted by screws which stopped the foot of the middle plate any where between actual contact and the space of

F

half

half an inch. When this doubler was completed and its insulating pillars entirely deprived of adhering electricity by melting the surface of the sealing wax which covered them, the doubling process was tried, and it produced negative electricity at about ten operations, so that this instrument tho' free from all accidental excitement was yet possessed of spontaneous electricity. But when I counted the doublings and applied an insulated candle to the first and second plates alternately, I cou'd easily collect and distinguish atmospheric electricity in a small room, tho' the doors and windows were shut, this I tried upon the supposition that the air would not be entirely deprived of its electricity by passing through small openings.

The next improvement I had in contemplation was a revolving doubler, and before I had finished my contrivance, I was informed that Mr. Nicholson had made one on the same principles, and intended to send it me, I therefore attempted nothing more till I received his very elegant and useful instrument, which is much the best mode of constructing my doubler hitherto attempted.

This doubler consists of two insulated and immoveable plates about two inches in diameter, and a moveable plate also insulated which revolves in a vertical plane parallel to the two immoveable plates, passing them alternately. See plate 2.

The plate A is constantly insulated and receives the communicated electricity. The plate B revolves, and when it is opposite the plate A, the
connecting

connecting wires at the end of the cross piece D must touch the pins of A and C at E F, and a wire proceeding from the plate B must touch the middle piece G, which is supported by a brass, wooden, or other conducting pillar in connection with the earth. In this position if electricity be communicated to the plate A, the plate B will acquire a contrary state, and passing forwards, the wires also moving with it by means of the same insulating axis, the plates are again insulated till the plate B is opposite to C, and then the wire at H touches the pin in C, connecting it with the earth, and communicating the contrary state of electricity to that of B but of the same kind with that of A. By moving the handle still further B is again brought opposite to A, and the connecting wires joining A and C. they both act upon B. which is connected with the earth as before, and nearly double its intensity, whilst the electricity of C is absorbed into A; because of the increased capacity of A, whilst opposed to B, capable by its connexion with the earth of acquiring a contrary state sufficient to balance the influential atmospheres of both plates.

Thus by continuing to revolve the plate B, the process is performed in a very expeditious and accurate manner.

The ball (I) is made heavier on one side than the other, and screw'd upon the axis opposite to the handle, to counterbalance the plate B, which may therefore be stopped in any part of its revolution.

Yet notwithstanding the convenience and accuracy of this doubler it always produced spontaneous electricity, even after all the refinous substances used in its construction had been melted over a candle, and after standing a long time with its plates in connection with the earth. I therefore conjectured that this spontaneous electricity was not owing to accidental friction, but to the increased capacity of approximating parallel plates which might attract and retain their charge tho' neither of them were insulated. To prove my hypothesis I first endeavoured more effectually and speedily to deprive the instrument of the electricity last communicated, and that I might know whether this spontaneous charge supposed to arise from the increased capacity of the parallel plates, wou'd be always of the same kind.

To effect this deprivation I connected the plates A and C together by a wire hooked at each end upon two small knobs on the backs of the plates, the middle of the same wire touching the pillar which supports the doubler. Another wire was hooked at one end upon the back of the plate B, and at the other end to the brass ball which counterbalances this plate. Thus all the plates were connected with the earth, and by turning the handle of the doubler, it might be discharged of electricity in every part of its revolution.

After often trying this method of depriving the doubler, I observed that its spontaneous charge was almost always negative. I then touched A and C with a positively charged bottle, and turned the doubler

doubler till it produced sparks for a long time together; and after this strong positive charge I hooked on the wires as above, and revolved the plate B about an hundred times, which so deprived the doubler of its positive electricity that when the wires were taken off, it produced a negative charge at about the same number of revolutions which it required before.

The positively charged bottle was again applied, and the wires being hooked upon the plates, as before, B was revolved only fifty times, yet this was found sufficient to deprive it of its positive charge, and in many experiments five or six revolutions were sufficient; but I never thought it safe to stop at so few, and have therefore generally turned the handle forty or fifty times between every experiment.

Left electricity adhering to the electrometer shou'd obstruct the above experiments, I did not let it stand in contact with the doubler during its revolutions, but touched the plate A with the cap of the electrometer, after I supposed its electricity was become sufficiently sensible: but lest even this contact shou'd communicate any electricity, I made a cap for my electrometer of shell lac, having a small tin tube in the center, to which the gold leaf was suspended within the glass, and a bent wire was fixed to the top which might easily be joined to the plate A of the doubler, and thus the gold leaf was more perfectly insulated, and the electricity cou'd

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not be diffused over so large a surface. The glass which insulates the plates and cross piece of the doubler was also cover'd with shell lac.

The doubler and electrometer being now well insulated, I proceeded to try the following experiments to ascertain whether the spontaneous electricity was attracted by the approximation of uninsulated parallel plates.

EXPERIMENT I.

The doubler was deprived of electricity by revolving the plate B forty times with brass wires hooked to all the plates, and during this deprivation the electrometer was connected with the plate A by means of a brass wire. I then took off the wires whilst the plate B stood between C and A, in the upper part of the plane of its revolution; and turning the handle towards the right hand, the gold leaf open'd negatively about a quarter of an inch, with twenty-one revolutions.

EXPERIMENT II.

The doubler was deprived of electricity, as before, and whilst the plate B stood parallel to the plate A, the brass wires were taken off, then turning the handle forwards, the gold leaf open'd a quarter of an inch negatively at the sixteenth revolution.

These experiments were repeated about thirty times, and on different days, without any considerable difference in the results; the number of revolutions

volutions being always greater when the plates set out from a single position than when the wires were taken off whilst A and B were parallel.

The plate B is placed at the distance of 1-16th of an inch from the other plates, and remains the same in the following experiments. It may be necessary to note this circumstance, for doubtless the number of revolutions, if not other results would vary, if the plates were placed nearer or farther asunder.

EXPERIMENT III.

A copper plate thirteen inches in diameter having its surface rather convex, was furnished with an insulating handle of oiled glass, four inches long and baked till the oil was well hardened. One end of the glass was fixed into a copper socket in the middle of the plate, and the other end into wood, that it might not be necessary to touch the electric part of the handle. This copper-plate was placed upon a mahogany table, and the doubler being deprived of its electricity, the plate B was placed parallel to A, so that B was connected with the earth, then the copper-plate was lifted up, by its insulating handle, and applied to the plate A, and lastly, the plate B being revolved only five times, the gold leaf diverged negatively to the distance of a quarter of an inch.

EXPERIMENT IV.

Left accidental friction against the mahogany table shou'd be objected, I lifted up the copper-

plate, and after touching it with the point of a needle, I applied it to the doubler, as before, and found that the doubler did not produce its spontaneous electricity at less than 15 revolutions; then touching the plate again, I lower'd it till a part of its convex surface touched the surface of some water contained in a large dish, and lifting up the plate, I applied it to the doubler, which caused the gold leaf to diverge negatively at five revolutions, as in experiment 3d.

EXPERIMENT V.

The plate B of the doubler was placed a little beyond its former position, so that its wire did not touch the middle piece, and consequently tho' most of its surface was parallel to the plate A yet it was insulated. The copper plate was then applied to B after it had touched the water as in the last experiment, and at the same time the plate A was touched by a brass wire, to connect it with the earth. About five revolutions produced a very sensible positive divergency of the electrometer, as might be expected in consequence of the negative charge being communicated to B instead of A.

EXPERIMENT VI.

By a frequent repetition of the foregoing experiments I was fully convinced of the attraction of electricity by approximating parallel plates: but hitherto the charge was negative, and suspecting that other substances might have a positive affinity with
the

the fluid, and especially if my conjectures concerning projected powders and vapours were true; I therefore cover'd the surface of the copper plate with a mixture of gum water and minium, also with gum water and wheat flour, and found that these substances when dried upon the surface of the copper, changed its electricity, so that when it was applied to the plate A, as in experiment 3d, it produced a positive charge, and when applied to B, as in experiment 5th, it produced a negative charge, as might be expected if the painted copper plate by its uninsulated approximation to the surface of the mahogany table or water absorbed a positive charge,

EXPERIMENT VII.

To render the electricity of approximating plates more conspicuously sensible, I ground a brass plate three inches diameter with emery till it would adhere to the surface of a piece of black marble. This plate and marble therefore constitute a condenser in its original state. The marble being moderately warmed I pressed the brass plate upon its surface with the point of a brass wire, then lifting it up by its insulating handle I applied it to the cap of the electrometer, which caused the gold leaf to strike the side negatively.

I hope it will now appear evident by the precautions and experiments mentioned in this section, and from the known laws of electricity.

1st. That the doubler in its present state may be deprived of accidental or communicated electricity.
2dly.

2dly. That the principal cause of its spontaneous charge, is the attraction of electricity by the approximation of its parallel plates.

3dly. That this charge may be positive or negative, according as the plates, or touching wires are composed of substances which have a greater or less adhesive affinity with the electrical fluid.

4thly. That the causes of spontaneous electricity are common to the condenser both in its original and improved state, and to the doubler, and equal in them all as far as they are equal in their dimensions and powers.

5thly. That since the doubler may be composed of very small plates, and yet its power be equal to that of a very large condenser, its spontaneous electricity will be more easily overcome by a communicated charge than that of a condenser of equal power, and therefore experiments performed with it will be less liable to equivocal results; and lastly from these considerations I have ventured to presume that the instrument may be advantageously used and applied to the discovery of new and interesting facts in the science of electricity.

SECTION VII.

Experiments on the adhesive electricity of metals and other conducting substances.

HAVING fully proved by a frequent repetition of experiments, that the positive or negative spontaneous charge of the doubler depended upon the absorption or repulsion of the electrical fluid by the approximation of its parallel plates, and that by applying larger plates covered with minium or flour, its electricity might be changed at pleasure, it easily occurred, that if the spontaneous electricity in the beginning of the process was sufficiently weak, the mere contact of metals or other substances having a different adhesive affinity with the electrical fluid might also change it, and a new and interesting employment for the doubler be discovered.

This supposed effect of contact was confirmed by the following experiments, in which the doubler and electrometer were deprived of electricity, and used with the precautions and improvements mentioned in the last section.

EXPERIMENT I.

The spontaneous charge of the doubler having been negative, and being deprived of this charge by the usual method, the plate B was placed parallel
to

to the plate A, but so that B was not connected with the earth. The plate A was then touched with the blade of a knife, and the plate B at the same time touched with the point of a soften'd iron wire. With sixteen revolutions the gold leaf diverged about one third of an inch positively.

EXPERIMENT II.

The doubler being deprived of electricity as before, and the plate B placed as in the last experiment, the knife was applied to B instead of A, and the soft iron wire to A instead of B, which opened the gold leaf negatively at 15 revolutions.

These experiments were repeated very often, and the electricity changed each time, being always positive in the plate touched by the knife.

To distinguish so minute a difference of adhesive electricity, as that which might be supposed between two metals so nearly alike as harden'd steel and soft iron, wou'd appear incredible had not the frequent repetition of experiments confirmed it.

Being now well convinced of this fact I tried many other substances with various success, sometimes the charge wou'd change regularly for a long time together, by applying the opposed substances to A and B alternately, as in the above experiments; and sometimes with other substances the charge wou'd be quite uncertain.

But to remedy the uncertainty of the influence of metals or other substances as far as possible, and

to

to exhibit the effects of adhesive electricity to advantage, I made tables of experiments in which the substances to be tried as were applied to A or B are mentioned in the first and second columns, the number of revolutions in the third, and the state of electricity in the fourth.

The number of revolutions necessary to cause a divergency of the gold leaf sufficiently sensible, is by no means offer'd as an accurate measure of the strength of adhesive electricity, but at present I know of no better a way of comparing its effects,

TABLE I.

Lead Ore.	Lead.	Revolutions.	Electricity.
A. ———	B. ———	15. ———	P.
B. ———	A. ———	15. ———	N.
A. ———	B. ———	14. ———	P.
B. ———	A. ———	13. ———	N.
A. ———	B. ———	14. ———	P.
B. ———	A. ———	13. ———	N.
A. ———	B. ———	14. ———	P.
B. ———	A. ———	13. ———	N.
A. ———	B. ———	14. ———	P.
B. ———	A. ———	13. ———	N.

TABLE

TABLE II.

Lead.	Iron Wire.	Revolutions.	Electricity.
A. ———	B. ———	13. ———	N.
B. ———	A. ———	15. ———	P.
A. ———	B. ———	13. ———	N.
B. ———	A. ———	15. ———	P.
A. ———	B. ———	16. ———	N.
B. ———	A. ———	17. ———	N.
B. ———	A. ———	16. ———	P.
A. ———	B. ———	14. ———	N.
B. ———	A. ———	20. ———	N.
B. ———	A. ———	18. ———	P.

TABLE III.

Lead Ore.	Iron Wire.	Revolutions.	Electricity.
A. ———	B. ———	15. ———	P.
B. ———	A. ———	16. ———	N.
A. ———	B. ———	22. ———	P.
B. ———	A. ———	16. ———	N.
A. ———	B. ———	17. ———	P.
B. ———	A. ———	15. ———	N.
A. ———	B. ———	16. ———	P.
B. ———	A. ———	16. ———	N.
A. ———	B. ———	17. ———	P.
B. ———	A. ———	15. ———	N.

TABLE

TABLE IV.

Tin-foil.	Iron Wire.	Revolutions.	Electricity.
A. ———	B. ———	16. ———	N.
B. ———	A. ———	16. ———	P.
A. ———	B. ———	13. ———	N.
B. ———	A. ———	12. ———	P.
A. ———	B. ———	13. ———	N.
B. ———	A. ———	21. ———	N.
A. ———	B. ———	12. ———	N.
B. ———	A. ———	14. ———	P.
A. ———	B. ———	13. ———	N.
B. ———	A. ———	16. ———	P.

TABLE V.

Zinc.	Iron Wire.	Revolutions.	Electricity.
A. ———	B. ———	16. ———	N.
B. ———	A. ———	17. ———	P.
A. ———	B. ———	15. ———	N.
B. ———	A. ———	21. ———	P.
A. ———	B. ———	15. ———	N.
B. ———	A. ———	24. ———	P.
A. ———	B. ———	15. ———	N.
B. ———	A. ———	18. ———	P.
{ A. ———	B. ———	16. ———	N.
	B. ———	17. ———	N.
	B. ———	15. ———	N.
{ B. ———	A. ———	22. ———	P.
	A. ———	21. ———	P.
	A. ———	17. ———	P.

In

In the above five tables every experiment was made by double contact, and since the state of electricity was evidently changed, (except in a few instances) whenever the two opposed metals were applied alternately to A or B, there remained no doubt of the influence of these metals. Yet it was not very apparent whether it was the positive state of the one metal or the negative state of the other which prevailed. I therefore tried the effect of single contact, choosing two metals whose electricity appeared to be contrary, and touching A, C, and the cross piece, whilst B stood single in the upper part of its plane, with a positive metal in one experiment, and with a negative metal in the next, or, or applying the same metal to A, C, and the cross piece in one experiment, and to B in another, but in this last case B stood in the lower part of its plane. The reason of varying the position of B was, that the plate intended to acquire a contrary state to that produced by contact, might first be brought into connection with the earth; thus when A, C, and the cross piece had been touched, B came from its higher position into connection with the earth when brought parallel to A, and might then become contrarily electrified; and when B had been touched in the lower part of its revolution, C became connected with the earth when B was parallel to it.

TABLE

TABLE VI.

	Revolutions.	Electricity.
Lead ore applied to A, C, } and the cross piece, - }	14.	—— P.
Zinc applied in the same manner	18.	—— N.
Lead ore, - - -	13.	—— P.
Zinc, - - -	15.	—— N.
Lead ore, - - -	16.	—— P.
Zinc, - - -	16.	—— N.
Lead ore, - - -	15.	—— P.
Zinc, - - -	14.	—— N.
Lead ore, - - -	14.	—— P.
Zinc, - - -	16.	—— N.

By experiments of single contact in the above table, it now appears that the adhesive affinity of electricity to lead ore is positive, and to zinc negative.

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TABLE

TABLE VII.

In which zinc is again tried by applying it to A in the first six experiments, and to B in the six last, and also tried after the interval of several weeks when the air was much more dry.

Zinc.	Revolutions.	Electricity.
A. ———	12. ———	N.
A. ———	12. ———	N.
A. ———	11. ———	N.
A. ———	13. ———	N.
A. ———	10. ———	N.
A. ———	10. ———	N.
B. ———	13. ———	P.
B. ———	13. ———	P.
B. ———	15. ———	P.
B. ———	12. ———	P.
B. ———	12. ———	P.
B. ———	13. ———	P.

TABLE

TABLE VIII.

Lead ore applied to A and B alternately.

Lead Ore.	Revolutions.	Electricity.
A. —————	8. —————	P.
B. —————	19. —————	P.
B. —————	14. —————	P.
B. —————	24. —————	N.
B. —————	15. —————	N.
A. —————	8. —————	P.
A. —————	7. —————	P.
A. —————	10. —————	N.
A. —————	7. —————	P.
A. —————	7. —————	P.

From these experiments it appears that the adhesive electricity of the lead ore was not always so strong as to overcome the spontaneous charge of the doubler.

Gold, silver, copper, brass, regulus of antimony, bismuth, tutensag~~g~~ mercury, various kinds of wood, and stone, were tried by this method of single contact and appear'd to cause a positive charge. Tin was negative, and a large piece of zinc much more weakly negative than a thin plate of the same metal used in the above experiments; of these I defer making tables till I have the opportunity of improving the accuracy of the doubler. This may be done several ways which I shall here describe, hoping that some more experienced electrician will approve and execute them before I have leisure.

1st. In the course of my experiments I found that the force with which the touching wires passed the pins on the back of the plates, had some influence on the charge, which was also observed by Mr. Nicholson, and it may reasonably be supposed that the adhesive electricity of these wires may have some effect. I wou'd therefore chuse some metal which has the least influence. Gold wire may probably be the best, and instead of small wires to flirt against the pins, let stronger wires move a rowel like that of a spur, and let the cheeks in which the rowel is fixed be made to hold it harder or easier by means of a screw passing thro' the center of the rowel. Thus the contact of the touching wires may be regulated by these screws, and may perhaps so influence the spontaneous electricity, that either A or B may be made to prevail at pleasure or be exactly balanced.

2dly. It is evident that the capacity of the plates is increased as they approach to each other, and this
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increased capacity will in many experiments cause them to absorb that kind of charge which agrees with their own affinities, or of the touching wires, instead of being influenced by the substances intended to be tried. Let the plate B be moveable upon its axis that it may easily be placed at any distance, between actual contact and the distance of half an inch from the other plates, that a distance may be found which will produce the least spontaneous charge, and be more easily overcome by an intended delicate communication of electricity. It will be also necessary to regulate the distance on account of the dryness or moisture of the air. In dry weather I have found the spontaneous electricity to become sensible at fifteen revolutions or under, and in moist air at about forty, the distance of the plates and contact of wires being the same in both.

3dly. The spontaneous charge of small plates must be less than that of large ones, so that adhesive electricity communicated by single contact will be more likely to overcome such charge, for which reason principally, as well as for reasons of convenience, small plates are preferable; perhaps the size of a shilling would be sufficient.

4thly. The plates should not be covered with varnish or lacquer, lest they should retain electricity, and to prevent tarnishing, the plates may be gilt, or made of the metal used for reflecting telescopes.

5thly. The spontaneous charge is produced at fewer or more revolutions according to the velocity or regularity with which the axis of the doubler is

turned, so that a regular motion wou'd also add to the perfection of the instrument, which might be effected by means of a pendulum, and a vibrating doubler wou'd perform the process as well or better than any other. The wires touching with equal force, and in regular time, wou'd be a considerable advantage with respect to the accuracy of experiments, and a doubler of this construction might be made to continue its motion like a clock, so that insulated vessels containing chemical mixtures or growing vegetables, might be placed so as to receive its superfluous electricity, and be kept in a constant state of electrification.

I will conclude this section with observing that since electricity, like all other known fluids, adheres with more or less force to different substances, it affords a simple and very satisfactory theory of the excitation of glass and other electrics, used in the construction of electrical machines; for when the silk flap is rubbed by the revolving glass cylinder, it is brought into close contact, and electricity adhering more forcibly to glass is carried forward into the open air, which air having not been render'd negative like the silk, does not counterbalance the surface of the glass, and therefore its capacity being lessen'd, it emits the charge it had just absorbed. The amalgamated cushion assists the process by bringing a surface of a conducting quality and in connection with the earth into closer contact.

SECT.

SECTION VIII.

Observations on atmospheric electricity collected by the flame of a candle.

BEFORE I describe my observations on this subject of enquiry, it may be proper to mention such theory of atmospheric electricity as appears to me consonant to the general operations of nature, and deduced from the most rational systems of others, my own observation, or the contents of the foregoing sections, which the intelligent reader will easily apply to this purpose.

The intention of beginning with the theory is to give the reader, (who may not have attended to atmospheric electricity) an opportunity of seeing to more advantage the principles which these observations tend to confirm or illustrate, and thereby render them more interesting and pleasant.

Atmospheric electricity may be principally considered as it appears in two states of the air, that is transparent and cloudy.

1st. The transparent or clear air always contains a great quantity of water in solution, and is generally found to be in a state of constant positive electrification, yet not always of the same degree of intensity, nor is the atmosphere every where in the same state, for the higher regions from their more perfect

insulation, are more strongly electrified than the lower strata of air whence the earth is constantly re-absorbing this fluid, and the invisible vapours are undoubtedly more or less dense in different places according to the quantity of evaporation and condensation, depending on the variations of heat and cold, so that irregular spaces of air, perhaps in the form of clouds, yet invisible, will be electrified positively or negatively; and to restore the equilibrium, the appearances called falling stars are produced. Or if the equilibrium between much larger tracts of air is to be restored, large meteors such as that of the year 1783 fly with astonishing brilliance and rapidity from one region of the air to another.

The aurora borealis is another electrical appearance frequently seen in a transparent atmosphere, yet it is sometimes seen when there are clouds, and is probably owing to the diffusion of electricity in the highest and most rarified part of the atmosphere, where the air is not sufficiently dense to exhibit the electrical fluid in the form of corruscations or balls of fire.

2dly. When vapours are sufficiently condensed to become visible, the intensity of their electrification increases, and if the clouds thicken speedily, their sensible electrical atmosphere sometimes extends to the distance of several miles. This extensive atmosphere will act powerfully on the lower strata of vapour, (which may be considered as having an imperfect connection with the earth) and induce a negative state whose intensity will continue
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increasing with that of the super-incumbent cloud, till the equilibrium be restored by tremendous claps of thunder, with vivid corruscations of lightning. And if the cloud happens to be low, the earth itself becomes its immediate opponent, and is sometimes violently struck to the injury or destruction of its vegetable or animal inhabitants.

These are the chief and most striking effects of atmospheric electricity, and to account for them on the known principles of this fluid is the business of my present attempt.

The first and most difficult part of this investigation is to ascertain the general cause of sensible electricity in the air, and explain the particular manner in which it is absorbed from the earth. But from the late satisfactory experiments of Messrs. Volta, Lavoisier, De la Place, and De Saussure, the evaporation of water by the sun's heat may be confidently assigned as the true general cause, and this opinion I hope the reader will find in some measure strengthened by the experiments contained in section the fourth. And from the experiments on approximating surfaces, and on adhesive electricity in the sixth and seventh sections, I wou'd infer that when water is raised into the air by means of heat, electricity adheres more copiously under such circumstances to each rising particle from the general laws of the attraction of cohesion, and the very great elasticity of the electrical fluid; for a rising particle of water may be considered as in the situation of the copper plate, section 6th, experiment 3d and 4th, that
is

is surrounded with air except that it is connected with the earth by one point of contact. And if there is a difference between air and water as to their elective attraction of electricity, which from numerous corresponding facts may easily be admitted, it follows that the smaller the particles of water are, the more they come into contact with air, that is their surfaces bear a greater proportion to their solidity, and consequently they partake the more of the property of air as to their attraction of electricity; or the surface of air in contact with the water, has in this situation, the opportunity of absorbing electricity thro' the above-mentioned touching point: which electricity from the circumstances of approximation and contact, may be condensed and the particle of water be positively electrified tho' uninsulated.

It is for the sake of perspicuity that the vapour is here considered as rising in the form of small globular particles: but however that may happen, the electrical adhesion will probably be the same: for if the process of evaporation shou'd not consist in the ascension of globular particles raised by heat, but that it consists in a chemical combination of heat, air, and water, which instantaneously form a transparent fluid, this compound substance may have a greater adhesive affinity with electricity than the surface whence it rises, and therefore become positively electrified. And this last supposition is considerably illustrated by the experiments contained in sect. 4th, wherein it is seen that the mixture of various mineral, vegetable, and animal substances, with

with the evaporating water changed its adhesive electricity.

Vapour thus ascending electrified, and being combined with air and heat so as to form a perfectly transparent fluid, is in its weakest positive state, till the heat passes off either by diffusion in the circumambient air, by two currents of different degrees of rarity passing in contrary directions, or by the higher part of the atmosphere moving with greater or less velocity than the lower, each current being more or less cold than the other. In any of these situations the vapour will be condensed and increase the intensity of its positive charge, and some such causes acting at all times, produce a constant positive electrification of the atmosphere, even before the degree of condensation is sufficient to destroy its transparency.

During a space of fifteen years, F. Beccaria never observed a serene atmosphere to be negatively electrified; except in four instances, when there was great reason to believe it proceeded from the influence of distant clouds. See his treatise on artificial electricity.

When this kind of condensation happens in the higher and more insulated part of the atmosphere, where no equilibrium can be restored by an insensible diffusion of electricity, nor by striking suddenly into the earth, and when the intensity of this electricity is increased beyond the capacity of the vapour to which it is attached, it is formed into balls of fire; for any fluid will form itself into a globular figure

figure from its own attraction of cohesion, if this effect be not prevented by adhesion to other substances. These balls of highly condensed electricity then move off towards those parts of the air which are least electrified, diffusing electricity as they pass, till they are wholly dissipated and consequently disappear. This dissipation may be plainly distinguished by a train of fire which often follows the meteors called falling stars.

The same causes may be supposed to occasion the larger meteors, which being collected from and dissipated in more extensive regions of air, are more luminous, and attended with one circumstance which might be expected from a very great accumulation of electricity, that is a division of the ball into several parts towards the end of its course.

Whoever has seen electricity emitted from a large electrical machine, thro' a long and capacious exhausted tube of glass, may perceive a striking similarity between this experiment and the aurora borealis, and may reasonably conjecture that the electrical equilibrium being destroyed in the highest and most rarified part of the atmosphere is the occasion of this appearance, and that it is very high is proved by the converging direction of the streams; and since the streams sometimes appear to move about considerably, and to indicate an uncommon degree of electrification, I have frequently been induced to examine the state of the air with a very sensible electrometer, during a very luminous aurora borealis, but cou'd not distinguish either an extraordinary
quan-

quantity or motion of electricity. Perhaps other situations might be more favourable for such observations, and hence others have more confidently affirmed that their apparatus has been affected by it.

When the air has lost more of its heat and the condensed vapour becomes visible so as to form clouds or mists, the intensity of its electrification is increased, because the water is now formed into small globules whose surfaces proportionally lessen, as the globules increase in diameter, and from Dr. Franklin's experiment of the can and chain it has been long known that lessening the quantity of surface exposed to air, increases the intensity of electrification. Mists or fogs which are only thin clouds near the earth are generally found to be electrified strongly positive, so that a kite having a metallic string and raised in misty weather will produce pungent sparks. But when clouds fly over a transparent air, and are in a still stronger state of electrification, it often happens that their atmosphere drives into the earth the electricity contained in the lower stratum of vapour, or that contained in some part of the cloud which from its situation can be most easily discharged thro' its imperfectly conducting connection with the earth.

A part of the cloud thus render'd negative is frequently separated from the positive part, by the different currents of wind, or when the higher part of the cloud moves with more or less velocity than the lower, in this case the negatived vapour will
pro-

produce a sensible atmosphere, and hence the clouds appear sometimes positive and sometimes negative.

To illustrate this effect of strong electrical atmospheres, the reader may try experiment the 8th, sect. 2d. And that a negative atmosphere will become sensible even upon a body floating in air whose positive state is the only cause of such atmosphere, is easily tried by first causing the air of a room to be strongly electrified positively, and then a small slip of gold leaf thrown into the air will acquire a negative state as it leaves the hand, and will be repelled by the approach of a finger or other conductor. In this experiment the finger has a sensible negative atmosphere as well as the gold leaf, tho' it be not insulated.

In summer altho' the hygrometer indicates a drier air, yet there is undoubtedly more evaporation, and therefore more water combined with or diffused in the atmosphere. The surface of the earth is hotter, and yet the higher part of the atmosphere, owing to its transparency and distance from the earth is not heated in the same proportion. In short every natural process is quickened or retarded by the active influence of the sun, and if vapours can now be more suddenly raised, they may also be more suddenly condensed, and under these and other favourable circumstances, the clouds become electrified to a much higher degree of intensity, till the equilibrium of the differently electrified strata, is restored by explosions termed thunder and lightning.

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The concurrence of two oppositely electrified clouds has sometimes been thought the immediate cause of thunder, and it is certainly possible that such clouds may now and then be driven by opposite currents so as to cause an explosion, but I think it is more agreeable to the most common appearances of the clouds to account for it by the extensive and powerful influence of electrical atmospheres, whereby the several parts of the cloud or surface of the earth are render'd positive or negative, as explained above; for it will not otherwise be easy to account for the quick and frequent succession of explosions which are perceived in a single and distinct cloud, every part of which is apparently moving in the same direction. But on the supposition of a negative stratum, occasioned by a powerful positive atmosphere, as long as a rapid condensation of water takes place, so long may a repetition of explosions be expected.

The following experiment may serve to illustrate the process of atmospheric explosions as far as relates to the influence of powerful electrical atmospheres.

Let two slips of gold leaf or rather white Dutch metal be fasten'd to a brass ball suspended by a silk string, or other insulating substance. Bring the brass knob of a charged bottle towards the points of the metallic slips till they become charged with electricity, which will cause them to be repelled each way from the knob of the bottle and stand as in plate 3d, fig. 3d. Continue to hold the bottle in the same position during a few seconds, and one of the slips will bend towards the knob of the bottle
fig.

fig. 4, and strike it suddenly, then it will stand repelled till its electricity be again diffipated. In this manner it will continue to repeat the stroke as long as a sufficient quantity of electricity remains in the bottle, unless the air be very dry, and then this experiment may fail, which with me has only happened twice.

After this short account of my ideas of atmospheric electricity, I now proceed to describe the instruments I have made use of in making observations.

The most common apparatus hitherto used has chiefly consisted of high pointed and insulated conducting rods, or wires extending from the place of observation to the top of an high building or steeple, and connected with an electrometer, or the small and insensible communications of electricity have been collected by means of Mr. Volta's condenser. But these instruments are generally either not sufficiently sensible, or they can only shew the state of atmospheric electricity at intervals, whence the observer loses the opportunity of watching the momentary and interesting change which happens in several states of the atmosphere, especially during the passage of thunder clouds.

In sect. 2d, exp. 20th, 31st, and 32d, it was found that the flame of a candle was very useful in rendering the atmospheric electricity sensible when it could not be perceived by means of points; this I believe it does because the effluvium of the candle, which is of a conducting nature, becomes combined with

with air so as to form a very compleat union, and as the rarified air so combined with phlogistic efflu-
vium rises upwards, it is continually succeeded by
a fresh quantity, and hence the apparatus has the
opportunity of absorbing electricity much more co-
piously than the sharpest points. Considering this
advantage I provided a deal rod about 10 feet long,
(see plate iii. fig. 2d,) and after the smaller end was
well dried it was fastened into a long tinn'd iron
funnel with cement, so that the funnel did not where
come within half an inch of the end of the rod; by
this means it is kept dry, and the funnel is not so
liable to be accidentally broken off as if it was in-
sulated by means of glass. At the small end of the
funnel is suspended the ring of a chain which sup-
ports a small lantern, containing a lighted candle.
To the lower and broad edge of the funnel a softened
brass wire is fastened, which is about the length of
the whole rod, and at the lower end is hooked to a
small ring near the thick end of the rod, that the
wire may not be liable to accidents when the instru-
ments is taken down. When this apparatus is used,
a window is opened in the highest room of the house,
and the rod is placed upon one strong nail and un-
der another, on one side of the casement, so that
the lantern is elevated about 50 degrees. Near the
place to which the rod is fastened is a hole in the
window frame of sufficient width to receive a tube
of glass cover'd with sealing wax, on the end of
which is a bent wire. The hook of the brass wire
is then taken from the ring, and hooked upon this

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insulated bent wire, which stands at a proper height to be connected with the cap of a gold leaf electrometer, standing upon a board under the wire, and that the brass wire may not be too much agitated by the wind a ball of lead is hung upon it. In this situation it is plain that the atmospheric electricity collected by the candle will come down the brass wire and be communicated to the cap of the electrometer, or to any other instrument. But as it very seldom happens that the gold leaf does not diverge when this apparatus is elevated, there is little occasion to make use of a condenser or doubler, nor even of a candle when there are large clouds passing over or rain falling.

OBSERVATION I.

May 24th, 1787. Several heavy clouds passed from the N. W. and the above described apparatus being elevated, the gold leaf diverged sometimes positively and sometimes negatively; at last a blacker cloud approached and rain began to fall, which caused the gold leaf to strike the sides of the electrometer negatively with increasing velocity till a flash of lightning and clap of thunder happened, and at the instant of the flash the gold leaf suddenly started open and then closed, and gradually open'd positively striking the sides about ten times, it then slowly closed and open'd negatively, and again struck the sides with increasing velocity till the second flash caused the same convulsive motion and sudden change
of

of its electricity; this was repeated several times during the passage of the cloud. When the thunder was more distant the opening of the gold leaf was less but yet very sudden, and at last the gold leaf frequently started open when no thunder was heard, or flash seen.

OBSERVATION II.

May 26th, 1787. Several showers passed over and electrified the apparatus first positively as the cloud approached, then it changed about the middle of the shower and ended negatively.

OBSERVATION III.

May 28th, 1787. The wind high and N. W. A shower of rain came on which electrified the apparatus first positively, the gold leaf continuing to strike the sides till the rain abated, then it became negative and it continued to strike more slowly till the rain entirely ceased, when it again changed and stood at about a quarter of an inch positive, and the sky became quite clear.

OBSERVATION IV.

June 7th, 1787. Wind S. W. and brisk. A shower coming on caused the gold leaf to strike the sides first negatively, then positively, and at the end of the shower again weakly negative.



OBSERVATION V.

June 8th, 1787. The sky was entirely overcast and small rain fell for several hours, which electrified the apparatus positively.

OBSERVATION VI.

June 25th, 1787. Wind W. Barometer 29. Thermometer in the house 64°. A little before one o'clock in the afternoon, the apparatus was elevated before the approach of a distinct and heavy cloud. The gold leaf diverged negatively slowly increasing till it began to rain, it then struck the sides and continued striking till the rain ceased, it then changed to positive and continued striking whilst fair; after some time it again became negative and struck quicker whilst it again rained, and some distant thunder was heard without moving the electrometer. Expecting more thunder, I hung up my watch near the apparatus that I might note down the time and changes of electricity, as they occurred during the passage of the cloud.

Hour. Min.

- | | | |
|---|----|--|
| I | 7 | Raining, electrometer striking quick negatively. |
| — | 10 | Electrometer striking more slowly. |
| — | 12 | Now changed to positive & opening slowly. |
| — | 13 | Thunder heard, striking slowly positive. |
| — | 14 | Very quick positive, yet raining. |
| — | 15 | More slowly positive. |
| — | 17 | Changing to negative. |

Hour. Min.

- I 18 Quick negative.
- 20 Thunder at a distance, still striking negative.
- 23 Still striking negative, raining slowly.
- 26 Still striking quick negative.
- 27 The gold leaf quite closed.
- 27½ Striking positively, yet raining slowly.
- 29 More slowly positive.
- 30 Rain ceased. Electrometer opening about an inch positively.
- 34 No sensible electricity. Some drops of rain falling.
- 39 Gold leaf open'd about half an inch positive, but decreasing.
- 40 Suddenly open'd positive, and then slowly striking. Heavy drops.
- 43 Decreasing positively. Raining.
- 45 Electricity insensible. Raining slowly.
- 46 Slowly opening negatively.
- 47½ Slowly opening positively.
- 48 An inch wide positive.
- 49 The gold leaf agitated and positive.
- 49½ Still agitated but changed to negative.
- 50 Opening negatively by starts till it strikes quick. Raining fast.
- 52 Ceases to strike, decreasing fast.
- 53 Changed to positive.
- 54 Striking positively.
- 55 The gold leaf struck the glass instead of the tin-foil.

Hour. Min.

- 1 56 Striking very quick positively.
 — 57 Slower and then very quick, still raining
 very fast.
 — 59 Distant thunder. Changing to negative.
 2 0 Striking quick negatively.
 — 1 Decreasing negatively.
 — 1½ Opening positively to the distance of an
 inch.
 — 2 Then changed to negative, and striking
 quick.
 — 4 Changed to positive, and then striking
 quick.
 — 6 Changing to negative.
 — 7 Striking quick negatively.
 — 8 Striking quick negatively.
 — 9 Striking quick positively.
 — 10 Still quick positively, and raining fast.
 Distant sky brighter.
 — 11 More slowly positive.
 — 12 Again quicker positive.
 — 13 Still quick positive. Sky clearing yet
 raining.
 — 14 Decreasing positively.
 — 15 Opening negatively. Rain slower and
 sky clearer.
 — 16 Standing wide negatively.
 — 16½ Decreasing negative.
 — 18 Rain ceased. Just sensibly positive.

Hour. Min.

- 2 18 $\frac{1}{2}$ Sun shining, and the gold leaf open'd to half an inch negatively.
- 20 A quarter of an inch pos. Sky clear.

In this observation there are 10 changes of electricity in less than an hour and a half.

OBSERVATION VII.

July 2d, 1787. Wind N. W. Barometer 29.45. Thermometer 68. Six o'clock in the evening. Unequal clouds covering the whole horizon, which caused a divergency of the electrometer of about half an inch positive.

OBSERVATION VIII.

July 14th, 1787. About two o'clock in the afternoon. Wind N. E. Heavy showers but clouds uneven. The gold leaf opened negatively, and moved irregularly till it slowly struck the side, and as the rain abated it opened less, but never changed to positive.

OBSERVATION IX.

July 15th, 1787. About half past seven in the evening. Wind S. E. An heavy shower of rain falling, the gold leaf struck the sides quick positively, and continued to do so about 10 minutes; it then became weakly negative, and stood at half an inch negative when the rain ceased.

OBSERVATION X.

July 15th, 1787. About eight o'clock in the evening another shower came on which began to open the gold leaf positively, increasing very slowly till it struck the sides whilst the rain increased, and when the rain came down quickest, it gradually changed to negative. The clouds then appeared very uneven, and often changed the electricity till the observations were discontinued.

OBSERVATION XI.

July 17th, 1787. About 6 o'clock in the evening. Wind N. W. A shower of rain electrified the apparatus weakly negative during the space of about half an hour without changing.

OBSERVATION XII.

July 25th, 1787. About one o'clock in the afternoon. Wind W. A heavy cloud approached and electrified the apparatus negatively a considerable time without rain; at last some drops falling the gold leaf struck the sides, and continued to do so till the rain ceased without changing to positive. The weather had been rainy for some days.

OBSERVATION XIII.

August 4th, 1787. Ten o'clock in the morning. Wind W. Barometer 29. 15. Sky very clear. The gold leaf opened just sensibly positive.

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OBSERVATION XIV.

August 12th, 1787. Wind W. Barometer 29. 1. Therm. 62°. The sky was overcast with uneven clouds, and a heavy cloud approaching it rained slowly, which gradually opened the gold leaf to the distance of an inch positively, then raining faster it suddenly collapsed and changed to negative, opening to half an inch whilst the rain ceased.

Two other clouds soon followed, which began positively and ended negatively as before.

A very extensive cloud succeeded the last and open'd the electrometer positively, which continued striking a short time; then it changed and struck negatively during about half the rain; it then changed and struck positively during the remainder of the shower, and when the rain ceased it open'd about half an inch negatively, where it stood for a few minutes and then collapsed, the sky clearing.

OBSERVATION XV.

About five o'clock the same day. The wind N. W. A shower began strongly positive and ended negatively as before. About six o'clock some uneven clouds passed over and the electrometer diverged negatively without rain, then rain falling it struck negatively a long time, then a heavier cloud approaching it changed and struck very quick positively, till the rain abated and the cloud was nearly gone, when it again changed and was weakly negative till the rain entirely ceased.

OBSER.

OBSERVATION XVI.

August 14th, 1787. About noon. Wind S. W. Very extensive clouds with small drizzling rain, the gold leaf opened about half an inch positively, which continued with very little variation about half an hour, it then rained somewhat faster and the electricity changed and continued about the same time negative.

OBSERVATION XVII.

August 16th, 1787. Nine o'clock in the morning. Wind quite calm. A thick mist. Electrometer open'd half an inch positively.

OBSERVATION XVIII.

August 18th, 1787. Half past twelve o'clock. Wind S. W. Thin white clouds had been passing over all the morning. A distinct black cloud approached and some rain fell before the apparatus was elevated, the electrometer open'd positively and continued opening but not striking till very heavy drops fell, it then changed and struck the fides negatively till the rain ceased. Its velocity abated when it was fair, but continued striking for about five minutes, it then decreased but continued open negatively till another cloud approached, it then open'd positively about half an inch, when it began to rain slowly, as the rain fell it open'd a little wider.

Hour.

Hour. Min.

- 12 45 About an inch positive. Rain ceasing
and gold leaf collapsing.
- 47 Electricity insensible.
- 47½ Opening slowly negative. Cloud ap-
proaching nearer.
- 48 A few large drops falling. Half an inch
negative.
- 50 Still half an inch negative, but drops ceased.
- 51 Decreasing. The clouds passed off, and
another approaching.
- 57 Still just sensibly negative. Cloud large
and likely to rain.
- 59 Beginning to rain. Opening to half an
inch negative, and then striking.
- I 0 Raining faster. Striking about twice in
a second.
- 1 Rain abated, yet striking negatively.
- 4 Yet striking negatively, but little rain.
- 5 More rain. Electricity decreasing. Cloud
about half over.
- 6 Electricity now increasing.
- 6½ Striking negatively.
- 7 Striking quick negatively, yet but little
rain.
- 8 Still quick negative. More rain.
- 10 So quick as to keep the gold leaf trilling
against the sides. Heavy rain.
- 12 Rain suddenly abating. Ceased to strike,
and decreasing.

Hour. Min.

- I 13 Changed to positive, striking slowly then quick. Few drops.
- 14 Trilling positively.
- 14½ Slower positive. Very few drops of rain.
- 15 Quite fair, yet striking slowly positive. Clear sky over.
- 17 Yet striking slowly positive.
- 19 Ceased striking, and decreasing. Sun shining.
- 20 Wide positive divergency, but decreasing very slowly.
- 24 Half an inch positive.
- 25 Just sensibly positive.
- 27 Insensible. Sky clear.

These clouds began and ended positively, and therefore it may be concluded that their proper state was negative, which occasioned on all sides an influential positive atmosphere.

OBSERVATION XIX.

August 25th, 1787. Twelve o'clock. Wind N. Barometer 28.63. Having rained all day, the electrometer open'd weakly negative, and sometimes changed to positive for a short time, but was mostly negative.

OBSERVATION XX.

August 27th, 1787. Two o'clock in the afternoon. Wind N. Barometer 29.3. A shower came

came on which opened the gold leaf slowly positive, which continued opening and closing whilst most of the rain fell, but did not strike the side. When the rain was nearly over it changed to negative, and then struck the sides for a considerable time after the rain had ceased.

OBSERVATION XXI.

Dec. 18th, 1787. Eleven o'clock in the morning. Mist covering the tops of the hills, which it had done for several days, sometimes descending into the valleys. The gold leaf diverged strongly positive: but upon the falling of some small rain it was found negative. The same happen'd on the 20th.

OBSERVATION XXII.

Dec. 25th, 1787. Wind E. Small snow falling all day. Gold leaf diverged strongly positive, tried several times.

OBSERVATION XXIII.

Dec. 27th, 1787. Wind N. E. Snow melting. A few white clouds. Electricity strongly positive.

OBSERVATION XXIV.

Jan. 1st, 1788. Wind S. A very thick mist, yet its electricity was but just sensibly positive, tho' whilst the mist was accompanied with frost and with an east wind it had been for several days so strongly positive as to be very sensible without a candle.

OBSER-

OBSERVATION XXV.

Jan. 2d, 1788. Wind S. Small rain. Electricity negative.

Jan. 6th, 1788. Wind S. Small rain. Electricity negative.

OBSERVATION XXVI.

Jan. 16th, 1788. High west wind. A cloud passed over and some sleet fell. The electrometer diverged strongly positive. The sky then clearing it became strongly negative, and decreasing changed to a weak positive when the sky was quite clear.

OBSERVATION XXVII.

Feb. 5th, 1788. Wind E. Thick mist on the hills, with small rain most of the day. Electricity negative except when the sky appear'd brightening, it then became positive a short time, and then when more rain fell it became again negative, and continued so most of the day. Constant rain seems mostly negative, because it probably forms a more extensive connection with the earth by moisture which weakens the positive and higher electricity, and strengthens the influential negative atmosphere.

OBSERVATION XXVIII.

Feb. 19th, 1788. Wind S. W. and gentle snow continued falling for several hours. The electrometer diverged about an inch positively.

OBSER-

D

OBSERVATION XXIX.

Feb. 20th, 1788. Wind E. No frost but a very thick mist. Gold leaf struck the sides positively.

OBSERVATION XXX.

March 5th, 1788. Wind S. W. and gentle snow continued falling from noon to five o'clock, the apparatus was elevated five times, and the gold leaf struck the sides positively.

OBSERVATION XXXI.

March 15th, 1788. Wind N. E. Snow had lain on the ground about a week, with hard frost, but now it was thawing and there fell some sleet. The gold leaf slowly struck the sides negatively.

OBSERVATION XXXII.

March 18th, 1788. Wind N. E. brisk. Overcast but fair. Electricity insensible with the candle, never observed so weak before.

OBSERVATION XXXIII.

March 21st, 1788. Wind W. One o'clock. A shower of hail came on which caused the gold leaf to strike violently positive. A little before the shower ceased it changed and struck negatively, and continued negative after the hail ceased and the sun shone for more than half an hour, slowly decreasing.

OBSER-

OBSERVATION XXXIV.

March 21st, 1788. Wind W. Three o'clock in the afternoon. A large cloud succeeded the last, the negative state of the air having continued till the cloud approached, which changed the electricity to positive, when being engaged this cloud could not be examined. At four o'clock a very large cloud came with rain, the electricity was found strongly negative, the electrometer could not come within 12 inches of its usual position without endangering the gold leaf; towards the end of the shower it changed from negative to positive several times. Once the change only lasted whilst the gold open'd and closed. At last it continued to strike negatively whilst the sky cleared, decreasing for about a quarter of an hour, it then changed to positive now fair, but a cloud approaching.

Hour. Min.

- 4 30 Electricity positive. Half open decreasing.
- 31 Closed. The cloud approaching fast.
- 33 Opening negatively. The edge of the cloud nearly over.
- 34 Still opening negative very slowly. No rain, very calm.
- 38 Little more opened. Cloud appears more broken.
- 41 Slowly decreasing.

4

43

Hour. Min.

- 4 43 A few drops of rain. Gold leaf almost closed.
- 45 Quite closed. No rain. Sunshines thro' a part of the cloud.
- 48 Still closed.
- 50 Opening positively. No rain.
- 56 Standing at half an inch positively.
- 5 0 Slowly decreasing. Cloud appears heavier.
- 4 Quarter of an inch positive. No rain. cloud still blacker.
- 9 Few drops of rain. Electricity the same.
- 17 No drops. Electricity rather increased. Cloud coming slowly.
- 19 Gold leaf diverges half an inch positive. No rain.
- 21 Gold leaf rather decreasing.
- 23 Quite closed. No rain. Cloud heavy.
- 25 Opening negative. No rain.
- 26 Half an inch negative.
- 29 Rather wider. No rain. Cloud still over.
- 30 Closed. Darker.
- 31 Opening positively.
- 32 Strikes slowly.
- 33 Striking quick positively, yet no rain.
- 34 Electrometer strikes at twelve inches from the wire.
- 35 A little rain.
- 36 A clap of thunder, and sudden start of gold leaf, yet positive.

Hour. Min.

- 5 37 Raining faster. Still positive.
- 38 Hailing fast, still positive, and striking at twelve inches distant.
- 39 Remarkable strong hail, striking quick at twelve inches.
- 42 Still hailing. Electricity ditto.
- 44 Still large hail. Electricity weaker.
- 45 Changed quick to negative, and striking at twelve inches distance.
- 46 Hail less. Electricity rather weaker.
- 47 Hail ceased. Electricity only opens negatively at three inches distance.
- 49 Fair. Electrometer in contact with the wire now positive.
- 50 Gold leaf just strikes the sides positively.
- 52 A flash of lightning and crack quickly following. A sudden stroke of the gold leaf which changed it to negative.
- 54 Striking negatively.
- 55 Electrometer removed to the distance of 12 inches, where it strikes quick negatively.
- 56 Striking more slowly negative.
- 6 0 Electrometer replaced striking negatively. Still fair.
- 1 Striking rather slower.
- 3 Still slower, and yet fair.
- 5 Gold leaf stands about an inch wide negatively.

Hour. Min.

- | | | |
|---|----|--------------------------------------|
| 6 | 7 | Closed, and then opening positively. |
| — | 8 | One inch pos. Small rain falling. |
| — | 9 | Strikes the sides positively. |
| — | 11 | Decreasing. Rain ceased. |
| — | 12 | Closed. Quite fair. |

The first thunder clap did not change the electricity; the second changed it from positive to negative, contrary to former observations; this must depend in some measure on the distance.

OBSERVATION XXXV.

April 13th, 1788. Nine o'clock in the morning. Wind S. W. Sky perfectly clear having been without clouds since the evening before. The gold leaf diverged about half an inch positively.

At twelve o'clock the same day the divergency was only about a quarter of an inch, and the same at eleven o'clock at night.

OBSERVATION XXXVI.

April 30th, 1788. The wind N. E. and very gentle. An hygrometer of whipcord, which moved in a space of 16 inches, marked in inches and eights moist and dry, reckoning up and down from the middle of the space, stood at $6\frac{1}{2}$ dry. The apparatus was elevated at 3 o'clock, afternoon, and the gold leaf opened half an inch positively. At half past 8 o'clock the hygrometer was risen about an

12

inch,

inch, and the gold leaf open'd so wide as nearly to strike the side. The weather all the time quite serene. The falling of the dew appeared to increase the divergency of the gold leaf.

OBSERVATION XXXVII.

May 1st, 1788. Seven o'clock in the morning. Wind N. E. gentle, serene, and perfectly clear. The hygrometer $3\frac{7}{8}$ dry. The gold leaf nearly struck the side positively.

About 11 o'clock the same day, hygrometer $5\frac{1}{2}$ dry, the gold leaf now opened only half an inch positively, still clear and hot.

At 12 o'clock the wind changed to S. W. yet very clear and hot. The divergency was less than quarter of an inch. Hygrometer $6\frac{1}{2}$ dry.

At 1 o'clock, the wind S. Divergency 1-16th of an inch.

At 2 o'clock the electricity quite insensible, clear, and very hot. Hygrometer 7 dry.

At 3 o'clock the gold leaf open'd $\frac{1}{2}$ of an inch positively. A few white clouds appear'd. Hygrometer $7\frac{3}{8}$ dry.

At 5 o'clock, clouds somewhat darker. Divergency quarter of an inch. Hygrometer $7\frac{1}{2}$ dry.

At

At 7 o'clock, fewer clouds, very calm. Divergency half an inch. Hygrometer $6\frac{1}{2}$ dry.

Half past 8 o'clock. Hygrometer 5 6-8ths dry. Divergency only quarter of an inch. Sky now clear.

Eleven o'clock at night. Hygrometer 5 6-8ths dry. Clear and calm. Divergency half an inch.

OBSERVATION XXXVIII.

May 5th, 1788. Half past 4 afternoon. Wind N. E. Having been clear all day. Hygrometer 6 4-8ths dry. Divergency $\frac{1}{2}$ inch positive.

At nine o'clock in the evening, Hygrometer $5\frac{1}{2}$ dry. Barom. 29. 3. Clear and calm. The gold leaf slowly strikes the fides positively.

OBSERVATION XXXIX.

May 6th, 1788. Near twelve o'clock at night. Barom. 29. 2. Hygrometer $5\frac{3}{4}$ dry. An heavy shower of rain lasted about half an hour, during which the gold leaf continued striking positively, and after the rain ceased it continued a long time striking positively, and never changed to negative. Since the weather had been so long dry, it is probable that the air was not sufficiently moist to conduct away the electricity, which wou'd have been otherwise repelled by the atmosphere of the cloud.

OBSERVATION XL.

May 17th, 1788. The wind N. E. whence it had blown above a week without rain. Hygrometer 5 dry. Barom. 29. 2. The air undoubtedly very dry. The slips of Dutch metal were suspended in the middle of a room as before described, and when the charged bottle was presented the slips of metal stood diverging and cou'd not be made to strike the knob as usual, which shews that a certain degree of moisture in the air is necessary to this experiment.

OBSERVATION XLI.

May 19th, 1788. Barom. 29. 15. Hygrometer 5 dry. Clouds moving slowly from the north and thickening in the south. at half past 2 o'clock the apparatus was elevated, and the electrometer struck the sides slowly positive for some time, then stood still at about an inch wide, and then started closer or wider several times, which was probably occasioned by distant thunder.

Hour. Min.

- | | | |
|---|----|--|
| 2 | 45 | A sudden change to negative, which open'd half an inch, and then closed and became positive. |
| — | 50 | Opening and closing positively. Darker in the south. |
| — | 55 | About quarter of an inch positive. |

2 56

Hour. Min.

- 2 56 Suddenly struck the side positively. and then stood at $\frac{1}{2}$ of an inch.
- 57 Closed.
- 58 Very slowly opening negative. More clouds.
- 59 An inch wide negative.
- 3 0 Suddenly collapsed, and then struck the sides negatively.
- 2 Strikes slowly negative.
- 3 Suddenly positive, then closed and open'd negative.
- 4 Closed suddenly, and then again open'd negative.
- 5 Suddenly changed to positive, and then closed and open'd negative.
- 6 Suddenly changed to positive, and then striking negatively.
- 7 Distant thunder heard, and the changes of electricity were so quick that they could not be distinctly noted.
- 15 A flash of lightning.
- 17 Another flash, and change from negative to positive, and at the same instant a loud clap.
- 18 A flash, and instant change from negative to positive.
- 19 Flash and instant change.
- 20 Flash and clap, sudden closing, but no change to positive.

Hour. Min.

- 3 25 Sudden change to positive, which continued some time, then gradually changed to negative. Darker but no rain.
- 27 Sudden change to positive.
- 30 A very slow change from negative to positive. Beginning to rain.
- 31 Striking quick positively.
- 32 Thunder heard. Closing, then sudden opening pos. Rain ceased.
- 35 Flash. Sudden close without changing, more rain. Negative.
- 37 Flash and sudden change to positive.
- 45 Heavy rain. Slowly opening positively.
- 46 Striking slowly positive. Raining fast.
- 50 Sudden change to negative, and thunder heard.
- 55 Standing negative, then suddenly striking negative, and presently again stopping without changing. Distant thunder. Rain ceased.
- 4 0 Opening slowly negative with a waving motion till it strikes.
- 10 Still waving negative. No rain. Sky cover'd with cloud.
- 15 A little rain. Changing slowly to positive.
- 22 Rain ceased, still positive without a waving motion.

4 30

Hour. Min.

- 4 30 Changed slowly to negative, without any perceptible change of weather.
- 35 Several changes without rain, except at the distance of two miles.
- 38 Another change to negative.
- 43 Small rain, still negative.
- 48 Slowly raining; striking negative; then waving and starting.
- 50 Raining faster, still striking negatively.
- 52 Distant thunder, without changing the electricity.
- 54 Raining fast, still negative.
- 5 0 Still raining fast, and electricity negative.
- 1 Suddenly changed to positive. Rain abating.
- 2 Rain ceased, still positive.
- 4 Fair, and gold leaf striking positively. Sky clearing.
- 10 Still clearer. Positive electricity decreasing.

OBSERVATION XLII.

May 24th, 1788. Ten o'clock at night. Barometer 29.05. Hygrometer 6 dry. Very calm and clear, with a very bright aurora borealis. The atmospheric apparatus was carried into a field, and the electrometer consisted of a needle and a spider's thread, with a very small bit of gold leaf fasten'd to one end and both the needle and spider's thread were

were suspended by means of the peg to which the slips of gold leaf were usually fastened. The same apparatus was also elevated in its usual place, but tho' the spider's thread open'd slowly and struck the sides positively, yet no agitation or other motion happened, by which the electricity of the aurora borealis could be distinguished from the common electricity of serene air.

OBSERVATION XLIII.

May 25th, 1788. Eleven o'clock at night, quite calm and clear, a little appearance of aurora borealis. Barom. 29. 06. Hygrometer $7\frac{7}{8}$. The spider's thread strikes the side, but not so often as the evening before.

OBSERVATION XLIV.

July 4th, 1788. A large cloud cover'd the horizon, and it continued raining about two hours, during which time the funnel without its lantern was elevated, and the gold leaf changed its electricity ten times, beginning and ending positively.

OBSERVATION XLV.

July 5th, 1788. Large dark clouds frequently passed over; therefore about 2 o'clock in the afternoon a kite was raised, with a soften'd brass wire in the string about 200 yards long. When the kite had been flying about an hour, a dark cloud appeared at a great distance, and changed the electricity

city from positive to negative, which increased till the cloud came nearly over, and some large drops of rain fell, and to secure the string from being wet I endeavoured to tie it on the opposite side of a post to which it was before fastened; but when my hand came near the string I received so severe a shock that my arm was deprived of sensation during a few seconds, and I was obliged to let the string go, first terrified at the supposed loss of my left arm, and then gratefully rejoicing to feel the returning sensibility after rubbing with the other hand. The explosion was heard at the distance of about 40 yards like the loud crack of a whip. The kite was raised often before and since this time, but without any remarkable appearance.

OBSERVATION XLVI.

July 30th, 1788. Ten o'clock at night. Barometer 29. 5. Hygrometer 4 6-8ths dry. The sky clear and very calm. The aurora borealis very bright. The apparatus with an electrometer made of a spider's thread, was elevated, but no irregular motion, or extraordinary quantity of electricity was perceived.

OBSERVATION XLVII.

August 16th, 1788. About 12 o'clock. Wind S. W. A large and well defined cloud passed over, which as it approached open'd the gold leaf positively; when about half over it changed and became

came negative whilst very heavy drops of rain fell. The gold leaf continued striking negatively to the end of the shower, and then continued diminishing about 20 minutes after the rain ceased.

OBSERVATION XLVIII.

August 24th, 1788. Between 1 and 2 o'clock, afternoon. Barometer 29.02. Thermometer 62°. Hygrometer 6 dry. Two clouds passed over, but not quite perpendicularly, and the electricity was wholly negative, and continued negative during the intervals; a third passed some what nearer and began negatively, but ended positively; a fourth came still nearer and blacker, which began and ended wholly positive. No rain fell during the passage of the last, and only a small quantity whilst the two first were passing.

OBSERVATION XLIX.

August 25th, 1788. Between 10 and 12 o'clock in the morning. Barometer 29.02. Therm. 60. Hygrometer 5 6-8ths dry. Two clouds passed on one side, which electrified the apparatus negatively; a small quantity of rain fell, and more at a distance; a third cloud came directly over, and then the gold leaf open'd positively till it was about half over, and then it became negative without rain.

OBSER-

OBSERVATION L.

Jan. 13th, 1789. Eleven o'clock in the morning. Wind E. Barometer 28. 8. Thermometer on the north side of the house 26 degrees. Hygrometer $1\frac{1}{2}$ dry, having been frosty and the ground cover'd with snow for several weeks. The wind now strong and snowing fast. The gold leaf continued slowly striking the sides positively. Another observation was made during a shower of snow which I omitted to note down, but found several changes from positive to negative as in showers of rain.



F I N I S.

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